2019 Emerald Ash Borer Training

for Master Gardeners

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An e-learning course presented by:

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PURDUE UNIVERSITY

APHIS

DNR Indiana Department of Natural Resources

Emerald Ash Borer | Situation and Management

for Master Gardeners

A Note to Users Outside IN

Certain aspects of this course, especially insecticide recommendations and limits, are specific to Indiana.

Regulations in your state may differ. Please check with your cooperative extension service for local insecticide specifics.

Welcome!

This program was developed by the Emerald Ash Borer (EAB) Education and Outreach Program at Purdue. It is designed to communicate the latest scientific research regarding EAB management.

You may exit the program at any time and log back in later to resume viewing the presentation.

After completing a test at the end of the program, you can print out a Certificate of Completion.

Emerald Ash Borer | Course Overview

for Master Gardeners

- **EAB Background**
- Signs and Symptoms
- To Treat or Not to Treat?
- Insecticide Options
- **Biological Control**

EAB Background

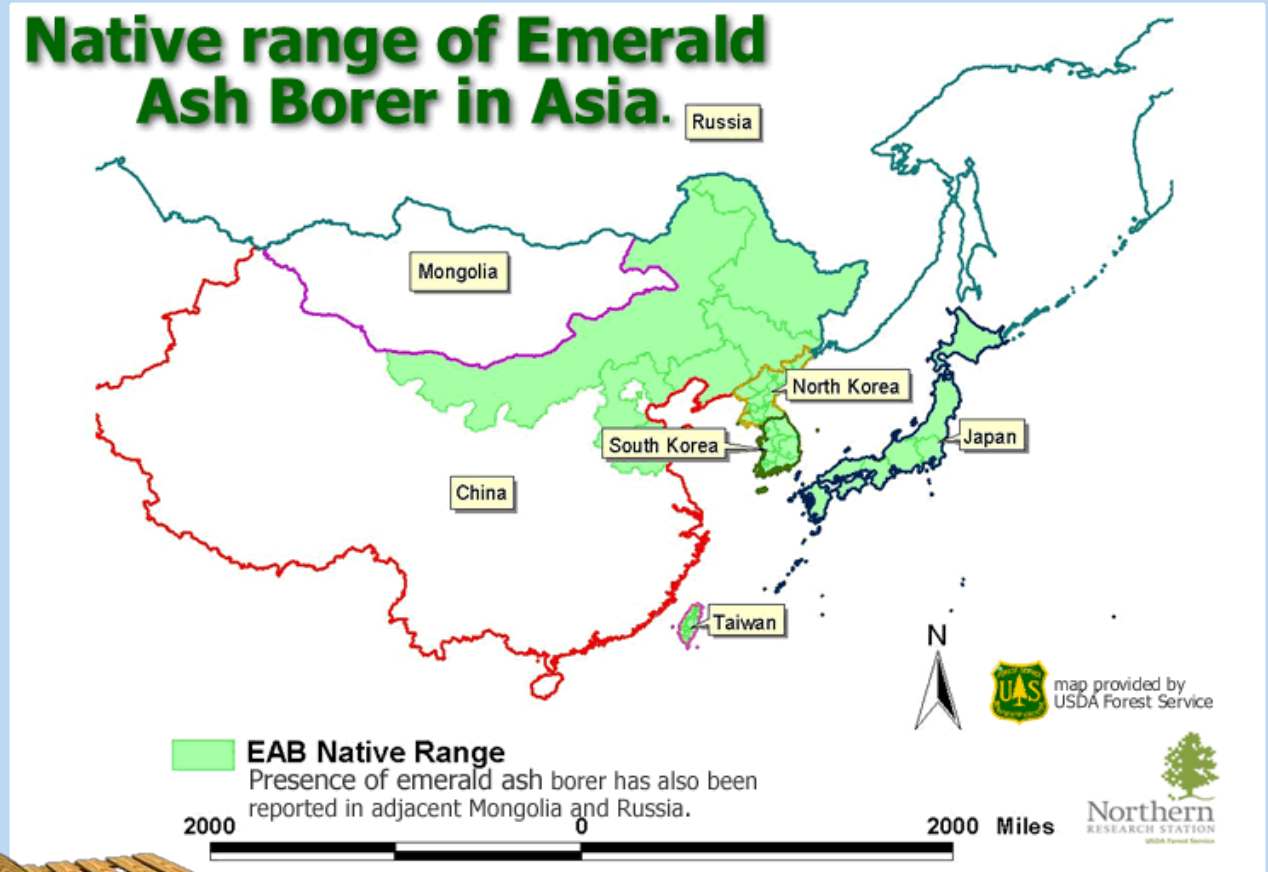
Learn about:

- Origin
- Lifecycle
- How EAB kills trees
- The ash resource and EAB's impacts

Emerald Ash Borer | Origin

for Master Gardeners

- Emerald Ash Borer (EAB) is an invasive, wood-boring beetle from Asia that attacks and kills North American ash trees (*Fraxinus* spp).
- EAB arrived in Detroit in the early 1990s in shipping material made from ash wood originating in Asia.
- EAB was not identified in Michigan until 2002 after thousands of ash trees in the area had already died.



- **In Asia, EAB is not a significant pest, and is actually quite difficult to find. Asian ash species, which have natural defenses against this insect, are only attacked when they are already weakened.**

Emerald Ash Borer | Origin

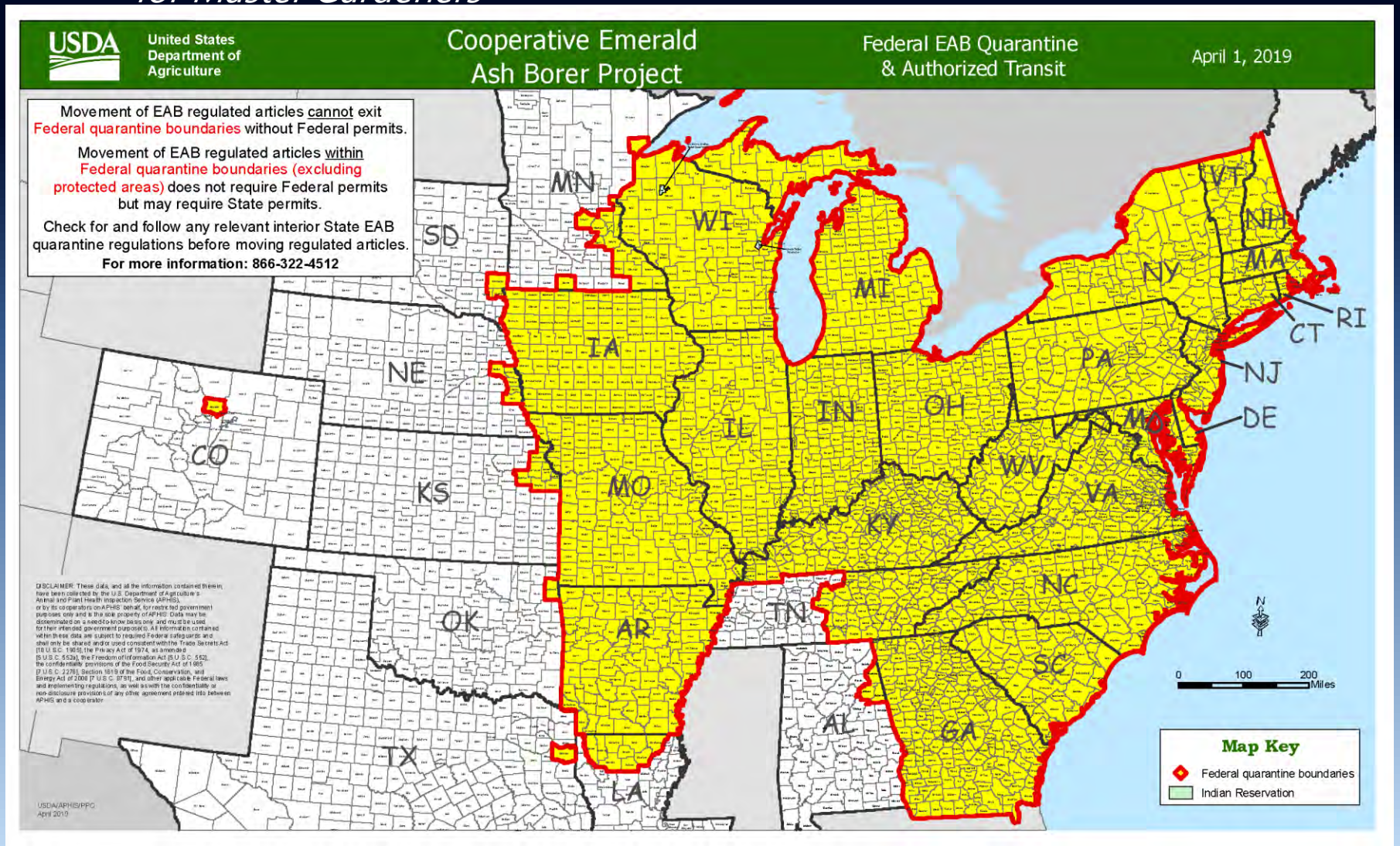
for Green Industry Professionals

- **EAB threatens an estimated 147 million ash trees in Indiana**
- **MOST native ash species are threatened with functional extinction**
- **It is the most devastating exotic forest pest in U.S. history.**

A neighborhood in Detroit after EAB killed all of its ash trees.

Emerald Ash Borer | Known Range

for Master Gardeners



Check EABindiana.info regularly for updates

Emerald Ash Borer | Life Cycle

for Master Gardeners

August - April

Emerald ash borer larvae spend this period in **diapause** in small chambers they excavate in the tissue under the bark of ash trees. Diapause is a time when an insect's growth and development stops and the insect is dormant.

April - May

When the sun begins to warm the tree in spring, the insect "wakes up" and resumes its development. First, the worm-like larva undergoes a major restructuring of its body form into that of a pupa. **Pupation** is the period during which the insect begins to develop into an adult form.

May - August

This is the insect's most active period. Around mid-May, newly formed EAB and begin to emerge from under the tree's bark through **D-shaped exit holes**. Newly emerged adults feed on ash leaves in the tree canopy for 2 weeks before mating.

Mated females deposit eggs on ash bark from which tiny larvae hatch. Newly hatched larvae burrow through the tree's bark and begin feeding on the tree's delicate circulatory tissue located directly beneath the bark. This destructive feeding continues throughout the summer.

Emerald Ash Borer | Life Cycle

for Green Industry Professionals

May- June

July

July- Sept

Larvae form characteristic s-shaped feeding damage underneath the bark

Oct - April

May

Emerald Ash Borer | EAB Adults

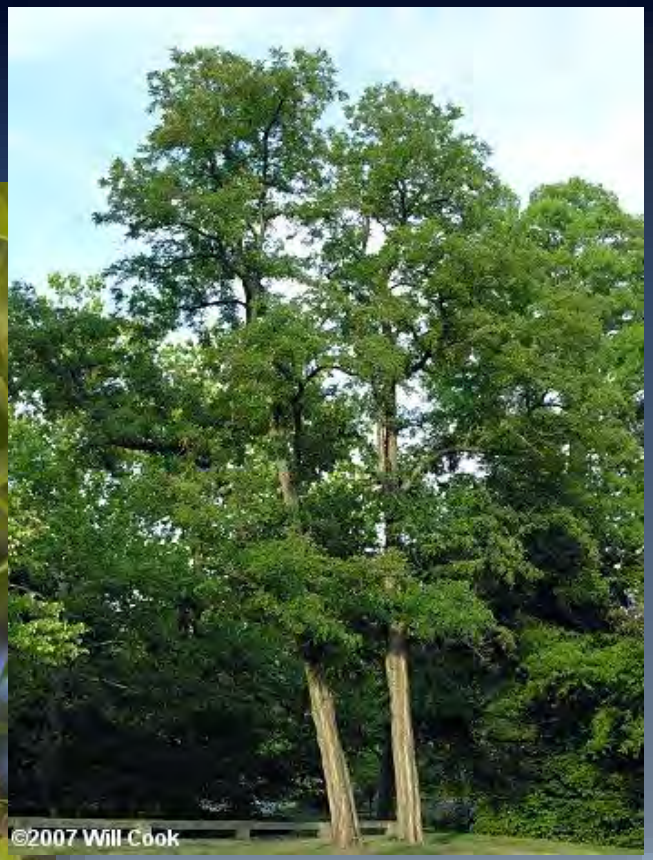
for Master Gardeners

EAB Adults:

- **Are very small green beetles.** You are unlikely to see them unless observing heavily infested trees.
- **Are strong fliers.** They usually only disperse ½ mile per year, but can fly up to seven miles.
- **Feed lightly on ash foliage.** This causes "notching" in leaf edges, but no significant tree damage.
- **Mated females deposit eggs on ash tree bark.** Each female lays about 75 eggs.

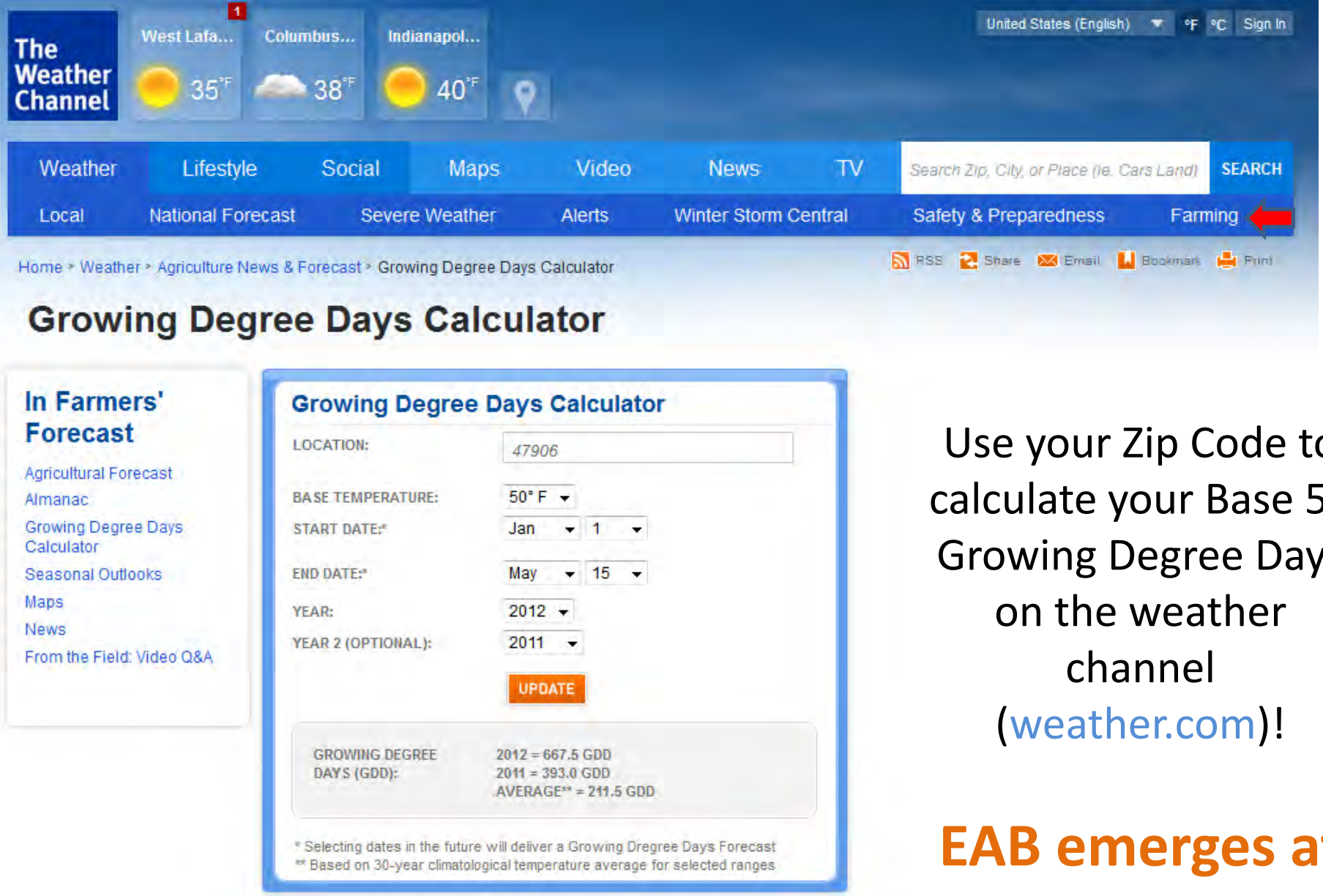
Tip: EAB adults begin to emerge from ash trees in May at almost exactly the same time as black locust trees begin to bloom, or 450 Growing Degree Days.

Look for the clusters of white blooms as a good indicator that the adults are flying.



Black Locust Trees
(*Robinia pseudoacacia*)

Note: *EAB does not attack black locust*



Use your Zip Code to calculate your Base 50 Growing Degree Days on the weather channel (weather.com)!

EAB emerges at 450 GDD 50

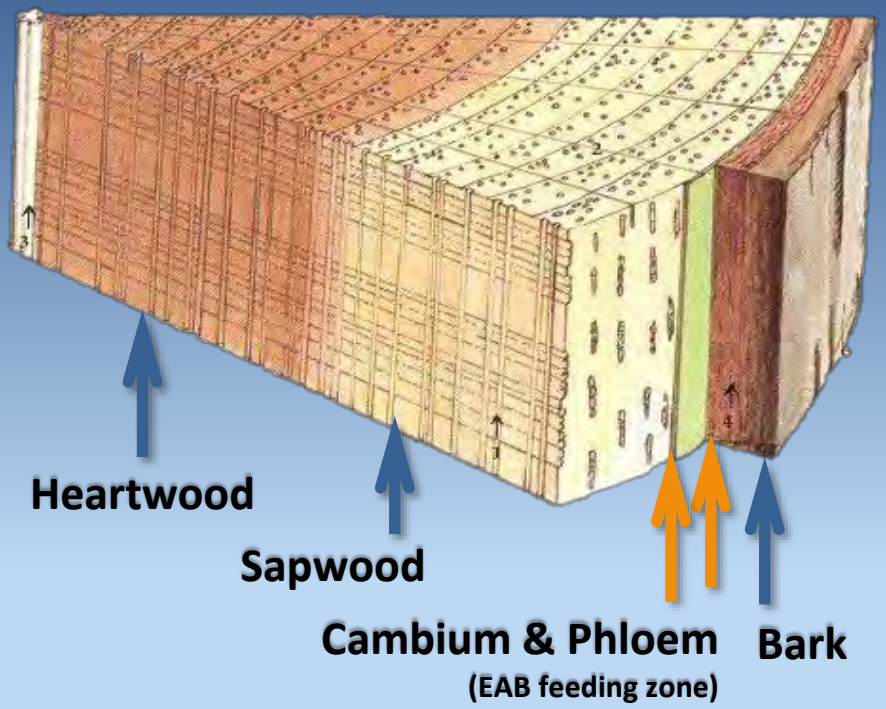
Emerald Ash Borer | How EAB Kills Trees

for Master Gardeners

- Larval feeding greatly reduces the tree's ability to circulate nutrients and water.
- Infested trees quickly starve to death, dry out, and fall.
- EAB attacks only true ash trees (*Fraxinus*).
- EAB kills **99.9%** of the untreated ash trees it attacks.

The juvenile, larval stage of EAB damages ash trees

Larvae feed on the tree tissues that are critical for nutrient and water transport. When the cambium and phloem are damaged by larval feeding, the tree starves to death.



Emerald Ash Borer | Larval Feeding Damage

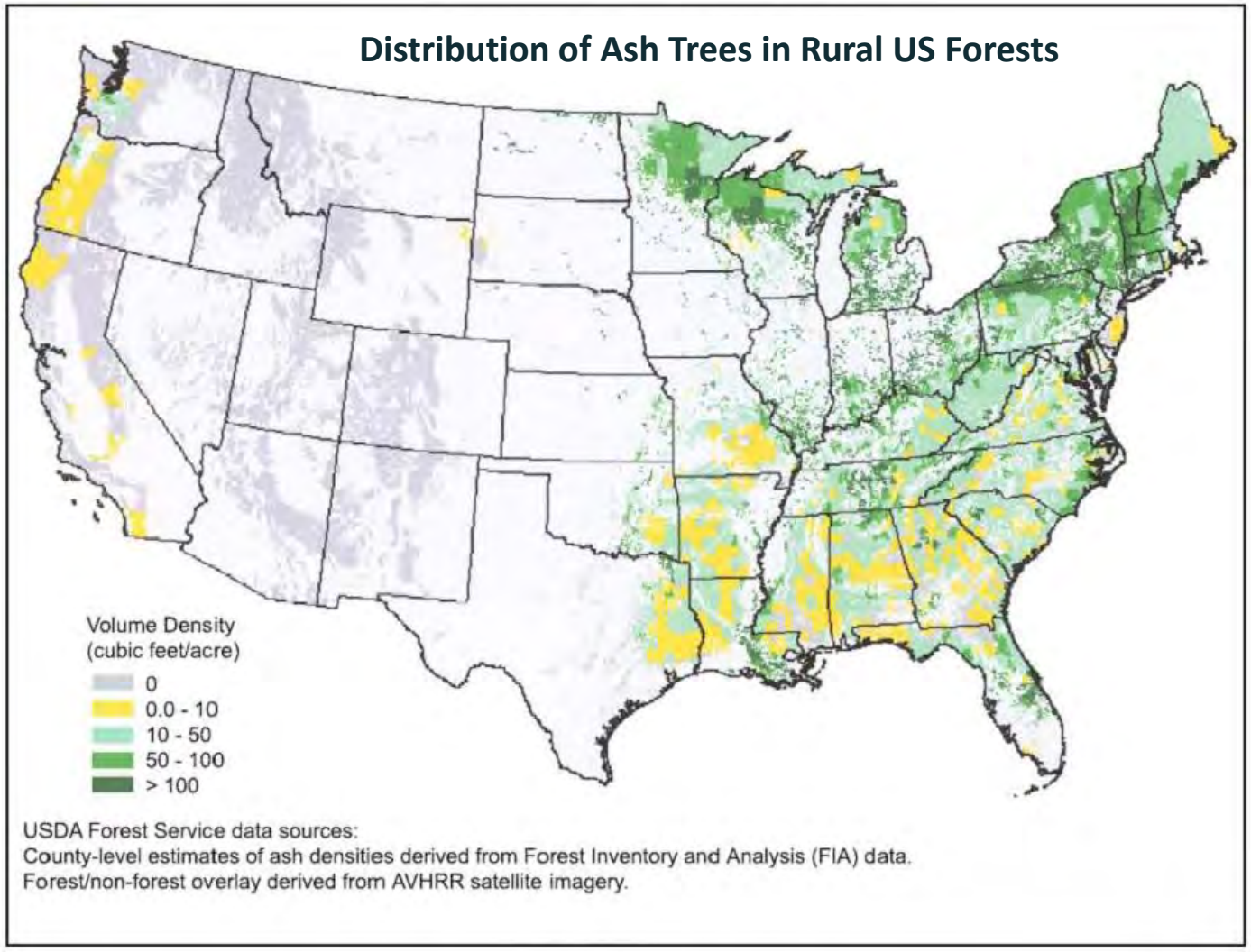
for Master Gardeners

- **ABOVE: An ash tree killed by EAB in a Steuben Co. campground.**
- **RIGHT: Characteristic s-shaped feeding galleries made by EAB larvae.**

Emerald Ash Borer | Ash Trees

for Master Gardeners

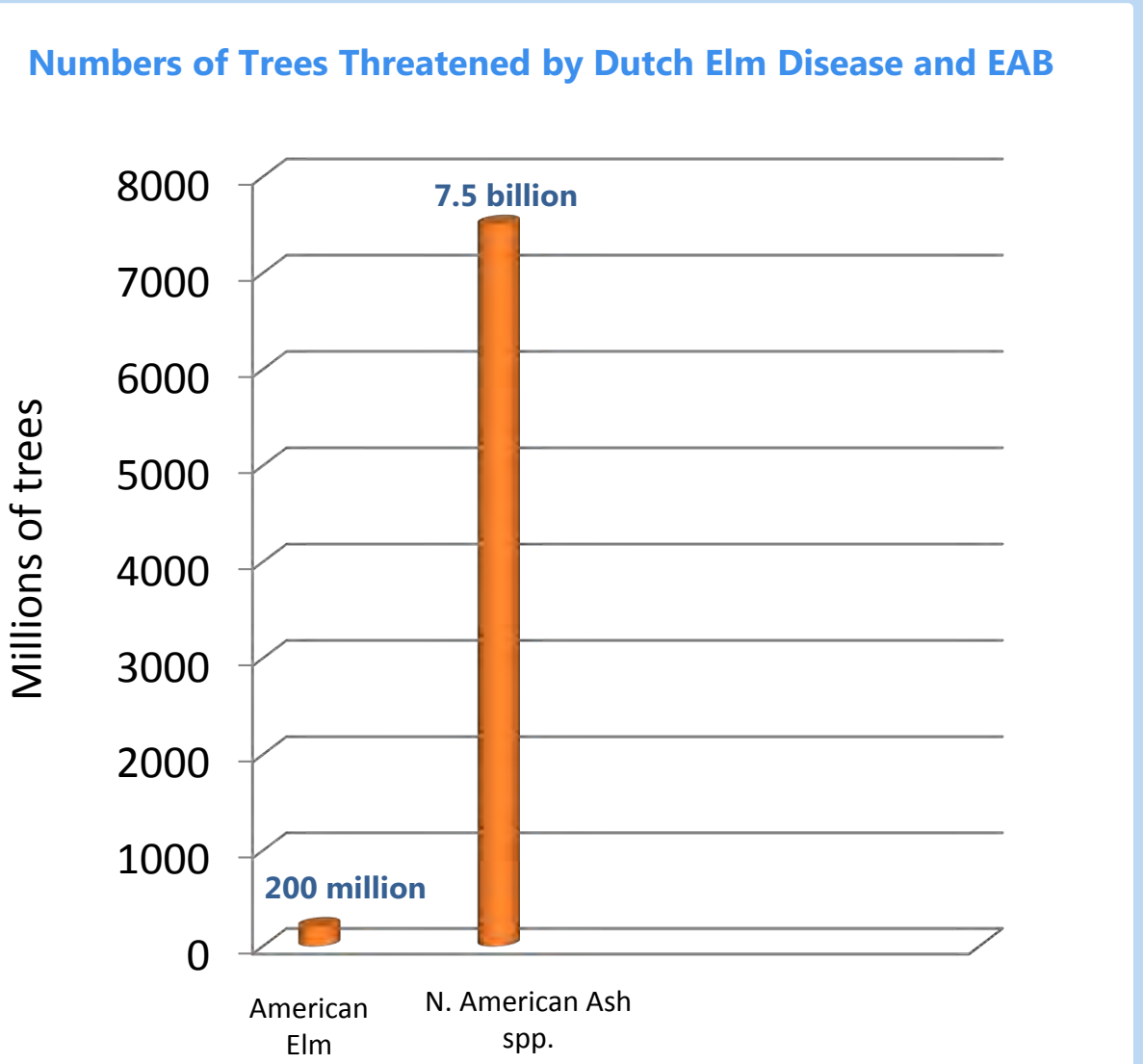
There are 7.5 billion ash (Fraxinus spp.) trees in America's rural forests and millions more in its urban forests.



Emerald Ash Borer | Ash Trees

for Master Gardeners

- Ash trees were widely planted for their fast growth and tolerance of urban stressors.
- EAB threatens an order of magnitude more trees than Dutch elm disease.
- In urban Midwest neighborhoods, ash trees commonly make up 20-80% of the forest.
- Ultimately, the EAB infestation is projected to cost $10.7 billion and encompass 25 states.



Emerald Ash Borer | Ash Trees

for Master Gardeners

Ash Tree ID

Branches and buds of ash trees are located directly across from each other (oppositely oriented).

Note: *Buds and limbs of ash trees often die and fall off, so not every single branch or bud will have an opposite mate.* **Look at several examples before deciding**.

Use "MAD BUCK" (Maple, Ash, Dogwood, Buckeye) to remember opposite branched trees in Indiana. Other tree species have alternate branching.


Ash trees have opposite branching and stout twigs.

Emerald Ash Borer | Ash Trees

for Master Gardeners

Ash Tree ID

Leaves are compound, feather shaped, and have 5-11 leaflets.

- **Leaflets are arranged opposite of one another**
- **Leaflet margins may be smooth, serrated, or toothed.**

Emerald Ash Borer | Ash Trees

for Master Gardeners

Ash Tree ID

Bark ridges on older trees form distinctive diamond-shaped patterns.

White Ash Bark

Paul Wray, Iowa State University, Bugwood.org

Green Ash Bark

Richard Webb, Bugwood.org

Emerald Ash Borer | Ash Trees

for Master Gardeners

Ash Tree ID

Seeds are single, oar-shaped samaras, borne in clusters near the ends of branches.

- **Ash trees have separate male and female trees. Only females bear seeds.**
- **Seeds may remain on trees until late fall or early winter.**

Emerald Ash Borer | Ash Trees

for Master Gardeners

Ash Tree ID

Male ash trees may have clusters of dark brown galls, caused by the ash flower gall mite.

A mix of old and new galls in an ash tree.
Purdue University P&PDL

Galls formed on male ash flowers by ash flower mites.
Whitney Cranshaw, Colorado State University, Bugwood.org

- **These galls form when tiny mites feed on male ash flower clusters early in the season, transforming them into bumpy, fringed masses.**
- **Gall damage is largely cosmetic.**

Emerald Ash Borer | Ash Trees

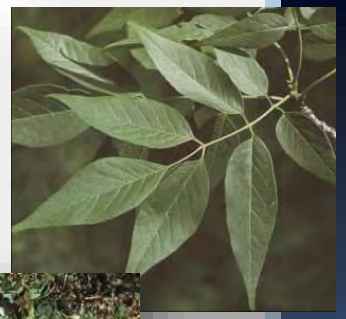
for Master Gardeners

Prefer drier areas

Prefer wet areas

Preferred Habitats of Indiana Ash Species

White Ash (*Fraxinus americana*) prefers areas where soils are rich and well drained; it has little tolerance for growing in wet areas.



Blue Ash (*F. quadrangulata*), like white ash, prefers dry uplands and doesn't like soggy ground. This species is resistant to EAB!!

Green Ash (*F. pennsylvanica*) is found in a wide variety of sites, but it naturally prefers poorly drained soils found along streams, in bottom lands, and throughout wet woods.

Pumpkin Ash (*F. profunda*), a less prevalent species of ash in Indiana, is found in bottom lands prone to flooding.

Emerald Ash Borer | Ash Trees

for Master Gardeners

Ash Wood…

- Is light colored, often used as alternative to red oak
- Has distinctive grain
- Is hard, elastic, and one of the strongest woods

Uses of Ash Wood

Ash is used in construction of items that require strength and resilience. It is the wood of choice for tool handles, bows, and professional wooden baseball bats.

It is also used commonly in woodworking and cabinetry. White ash in particular produces strong, durable wood, which is used in musical instrument construction, flooring, and veneers.

Unfortunately, ash also makes excellent **firewood.**

This is a problem because EAB larvae are easily transported under the bark of ash firewood.

EAB is often moved to new areas when people transport infested firewood.

Once it is split, it is often very difficult to differentiate ash from other hardwood firewood.

Firewood heavily infested with EAB

Trees Commonly Mistaken for Ash

Box Elder Trees (*Acer negundo*)

Box elder is the only other common tree with *opposite branching* and *compound leaves* in our region.

Box elder, is a type of ***maple* tree** and therefore *not susceptible* to attack by EAB.

The leaves are composed of three to five leaflets and are deeply toothed at the margins.

Jan Samanek, State Phytosanitary Administration, Bugwood.org

Like ash, box elder seeds are samaras, but each stalk bears two seeds instead of one.

Mountain Ash Trees (*Sorbus americana*)

The Mountain Ash Tree is not a true ash tree and is not attacked by EAB.

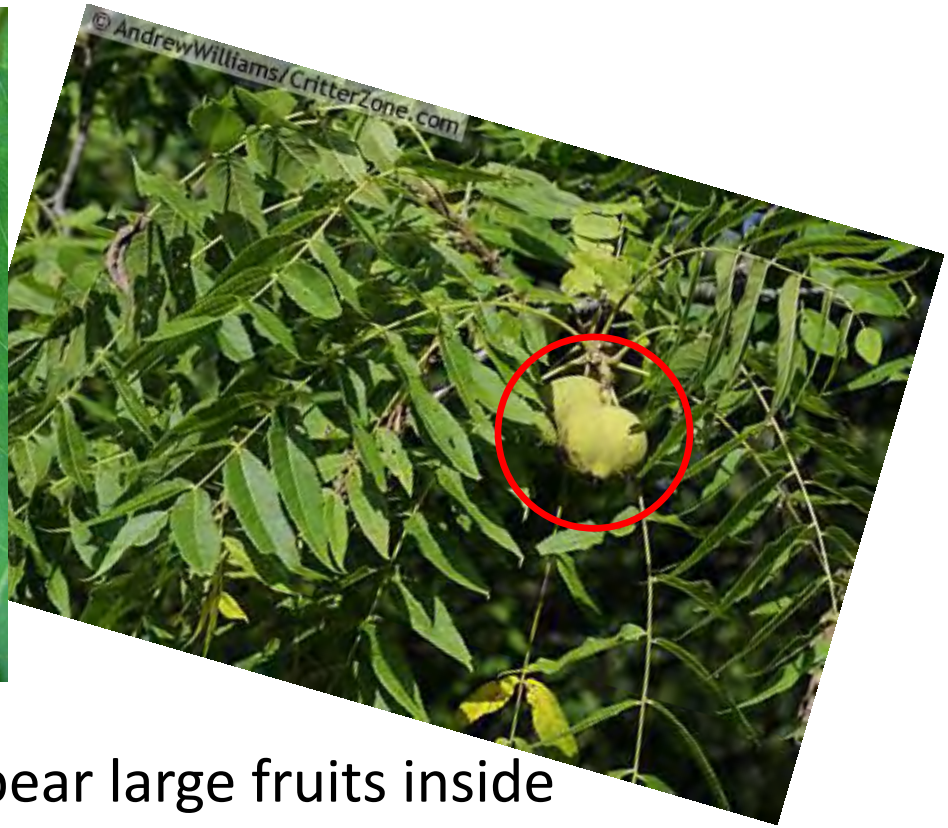
Mountain Ash has alternate branching.

Keith Kanoti, Maine Forest Service, Bugwood.org

Walnuts and Hickories (*Juglans* and *Carya* spp.)

Walnuts and hickories have compound leaves resembling those of ash, but are easily distinguished by their **alternate branching habit.**

http://departments.bloomu.edu/biology/ricketts/alternate_compound.html



Trees also bear large fruits inside green husks, not samaras.

Emerald Ash Borer | Course Overview

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- EAB Background
- **Signs and Symptoms**
- To Treat or Not to Treat?
- Insecticide Options
- Biological Control

Signs and Symptoms

Learn what to look for on potentially infested trees and look-alike damage.

Emerald Ash Borer | Basic Diagnostic Principles

for Master Gardeners

di•ag•no•sis: the process of determining the cause of a problem

There are many factors that can cause a tree to look sick. Don't immediately assume that a declining ash tree has EAB, especially if the insect has not been found close by. A systematic approach can help you make an accurate diagnosis.

HAS EAB BEEN FOUND CLOSE BY?

The Systematic Approach

Adapted from J.W. Pscheidt, "Disease Diagnosis and Control," The Pacific Northwest Plant Disease Management Handbook.
http://pnwhandbooks.org/plantdisease/diagnosis-and-testing/disease-diagnosis-and-control

1. Define the Real Problem
2. Look for Uniform or Non-uniform Patterns
3. Determine the Time Development of the Damage
4. Look for Specific Symptoms and Signs

Emerald Ash Borer | Basic Diagnostic Principles

for Master Gardeners

The Systematic Approach

1. Define the Real Problem

- Identify the tree and determine what it should look like at this time of year.
  It is important to know what is normal for the plant. For example, ash trees naturally leaf out later than most other trees in the spring, which is sometimes misinterpreted as a sign of stress or tree death.
- Determine which parts of the tree are affected.
  Describe what is actually wrong with the tree in terms of signs and symptoms. Is there wilting? Leaf loss? Cankers on the stem? Insect exit holes? Symptoms are sometimes manifested in plant parts that are not under attack.

A sign is physical evidence of the disease agent, like an EAB exit hole. A symptom is the physical expression of disease by the plant, like epicormic sprouting.

The Systematic Approach

2. Look for Uniform or Non-uniform Patterns

- Damage by non-living factors tends to be uniform.
  Damage may be seen on several different tree species, all of the plants in a particular area, or on the portions of the plants that are the same age.

- Damage by living factors such as insects or pathogens is typically non-uniform.
  Damage may be on scattered plants or scattered leaves and shoots on a single plant

The Systematic Approach

3. Determine the Time Development of the Damage

- Damage by living factors tends to spread over time.
  Damage may spread to different parts of the same plant, and/or from plant to plant within the landscape.
- Non-living factors tend to produce clear lines of demarcation between damaged and non-damaged tissues.

New shoot development after the terminal shoots were killed by frost.

Photo: Bob Hartzler

The Systematic Approach

4. Look for Specific Signs and Symptoms

- A tree species tends to suffer from several common maladies
  If you know a tree commonly suffers from a particular condition (like EAB!) you can begin matching observed symptoms with symptoms of that condition.

- Look closely! Signs may be very small or difficult to distinguish.

IMPORTANT:

Only proper diagnosis can lead to proper treatment of the problem.

Emerald Ash Borer | Signs and Symptoms

for Master Gardeners

Classic symptoms of EAB infestation

John Obermeyer, Purdue Extension Entomology

EAB attack produces a specific set of symptoms and signs on ash trees.

Other factors may produce similar symptoms and signs, however when these are present in combination, a diagnosis of EAB is almost definitive.

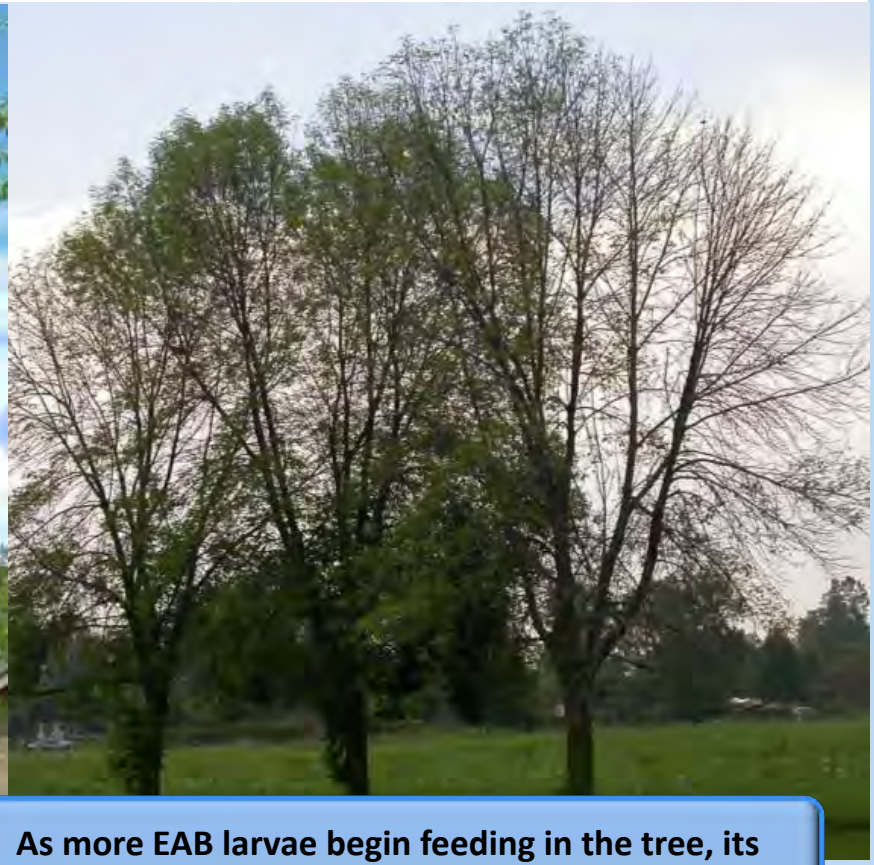
1. **Thinning of leaves in the upper canopy**
2. **Woodpecker activity**
3. **Presence of S-shaped larval feeding galleries under bark**
4. **Vertical splitting in bark**
5. **Presence of epicormic shoots**
6. **Appearance of D-shaped exit holes on bark**

Emerald Ash Borer | Signs and Symptoms

for Master Gardeners

1. Thinning of leaves in the upper canopy

Decline usually begins in the top 1/3 of the canopy. Leaves may be lost or appear smaller than normal.



As more EAB larvae begin feeding in the tree, its ability to circulate water and nutrients is destroyed, causing branch decline and death.

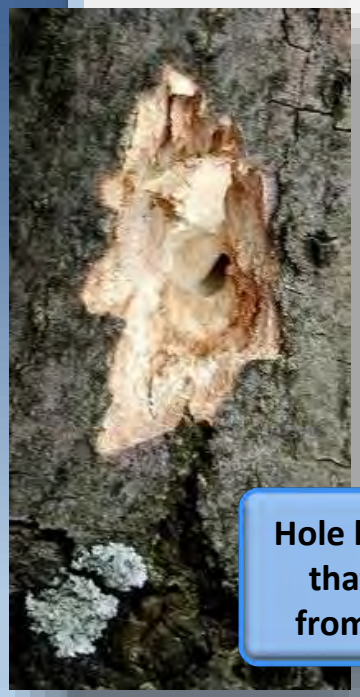
Emerald Ash Borer | Signs and Symptoms

for Master Gardeners

2. Woodpecker activity

Increased woodpecker feeding, especially during winter months, is a warning sign of infestation.

Woodpeckers are very good at locating EAB larvae under ash tree bark. They sometimes remove pieces of outer bark searching for them, leaving lighter patches on trunks of infested trees.



Hole left by a woodpecker that extracted an EAB from its pupal chamber


Holes left by woodpeckers feeding on EAB

Emerald Ash Borer | Signs and Symptoms

for Master Gardeners

3. Presence of S-shaped larval feeding galleries under bark

These zigzagging feeding tunnels are diagnostic of EAB in ash trees.

Feeding tunnels are packed with sawdust-like *frass*, or insect excrement.

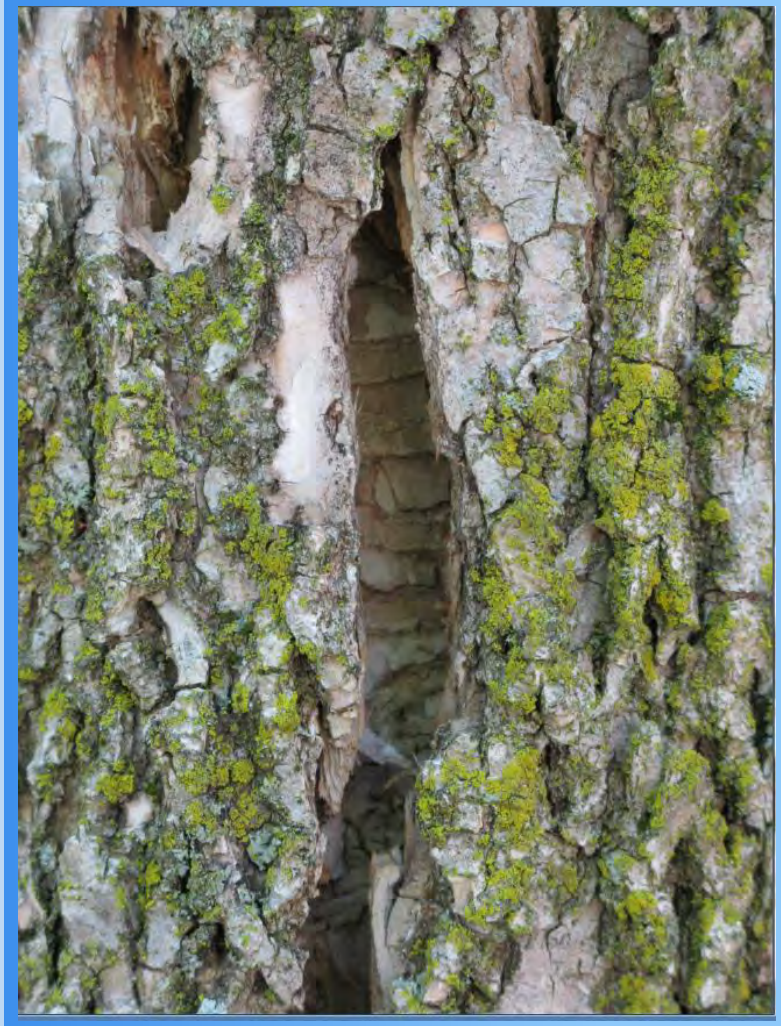
Daniel Herms, The Ohio State University, Bugwood.org

Emerald Ash Borer | Signs and Symptoms

for Master Gardeners

4. Vertical splitting in bark

Vertical splits occur when larval feeding kills vascular tissues underneath bark, causing it to die and split open.



Emerald Ash Borer | Signs and Symptoms

for Master Gardeners

5. Epicormic sprouting

Formation of epicormic shoots or "water sprouts" at the tree's base, on the trunk, or on large branches is a stress response to loss of leaves in the canopy.

Though leaves on these thin shoots may appear lush and healthy, they will not support the tree.

Heavy epicormic sprouting, such as that seen at left, often appears just before the tree dies.

Emerald Ash Borer | Signs and Symptoms

for Master Gardeners

6. "D" Shaped Exit Holes on Bark

Emerging adult beetles chew their way out from under the bark through tiny D-shaped exit holes. These holes are found on tree limbs and trunks.

Note their small size; they are about 1/8th inch wide. Exit holes made by native ash borers are typically larger and oval or perfectly round. By the time EAB exit holes are visible on the main trunk, the tree is likely heavily infested.

Daniel Herms, The Ohio State University, Bugwood.org

Emerald Ash Borer | Native Insects and Look-Alike Damage

for Master Gardeners


Steven Katovich,


James Solomon


Daniel Herms

Native Ash Borers

Several types of native North American insects have larvae that tunnel and feed under the bark of ash trees, sometimes causing enough damage to seriously harm trees.

Keeping trees healthy can help prevent infestation from native borers. Native borers usually only attack trees weakened by:

- Environmental stress (e.g. drought, frost)
- Mechanical injury from humans or storms
- Disease
- Old age

EAB will attack and kill weakened trees AND healthy, vigorously growing ash trees.

Emerald Ash Borer | Native Insects and Look-Alike Damage

for Master Gardeners

Longhorned Beetles : *Adults*

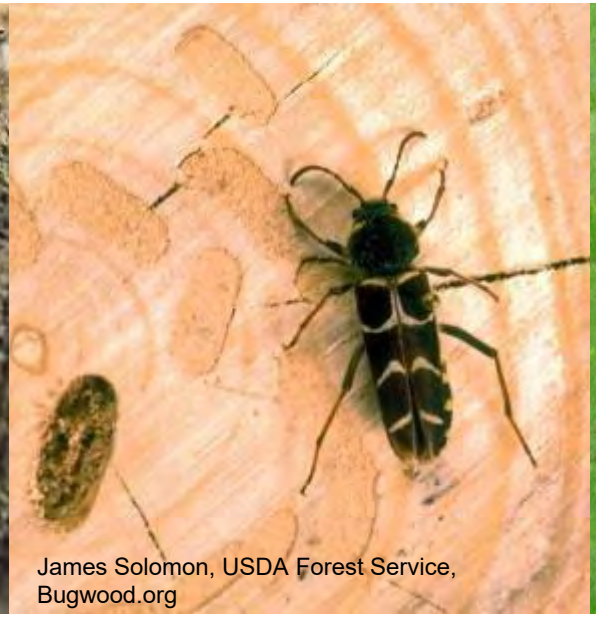
Red headed ash borer

Neoclytus acuminatus

James Solomon, USDA Forest Service, Bugwood.org

Banded ash borer

Neoclytus caprea



James Solomon, USDA Forest Service, Bugwood.org

Ash and privet borers

Tylonotus bimaculatus

Photo V. Burkle

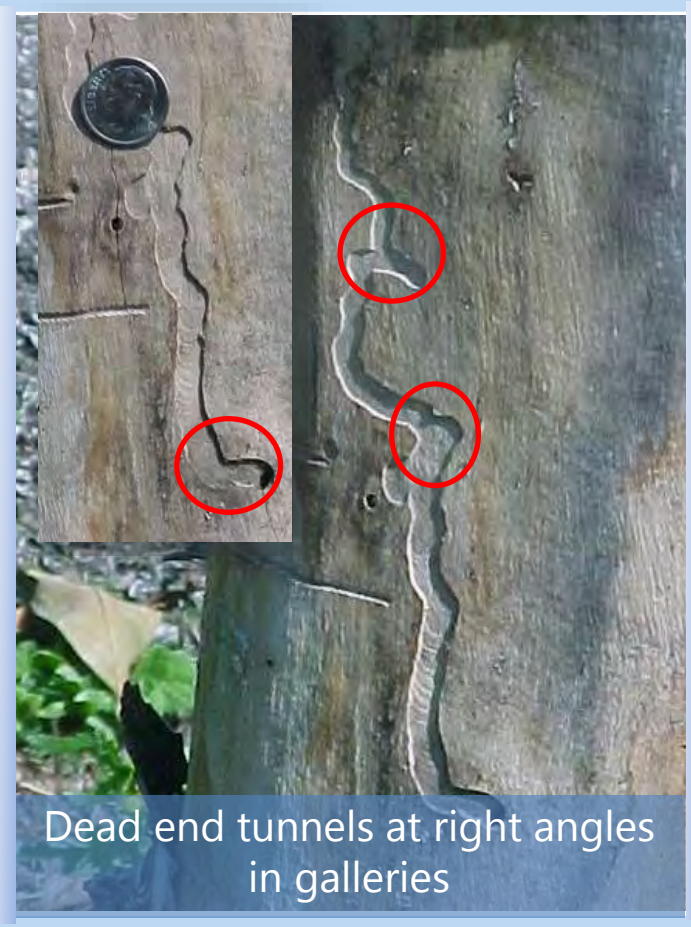
Emerald Ash Borer | Native Insects and Look-Alike Damage

for Master Gardeners

Longhorned Beetles : *Larvae*

Unlike EAB, longhorned beetles make:

Round exit holes



Dead end tunnels at right angles in galleries

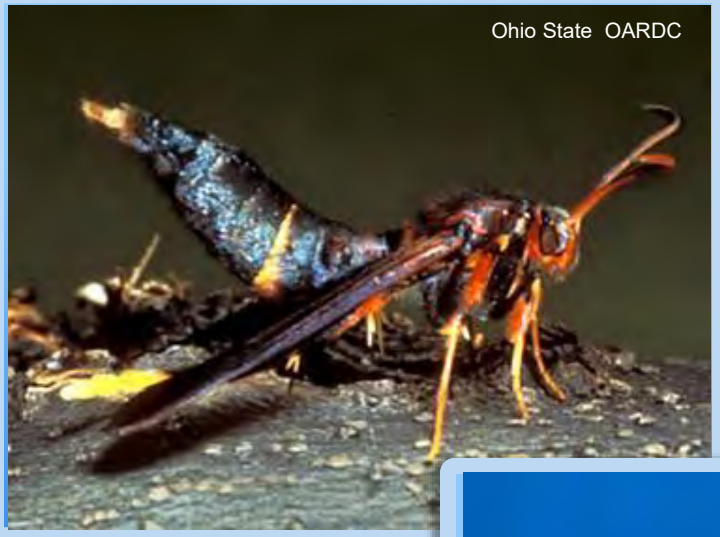
Galleries penetrating into heart wood

Emerald Ash Borer | Native Insects and Look-Alike Damage

for Master Gardeners

- There are many species of clearwing borers, specializing on different host plants.
- Adults closely resemble wasps but are actually moths. (lack stingers and have scaled wings)
- Moths are about 1 inch long with wingspans of 1-1/4 inches.

Clearwing Borers: *Adults*



Banded Ash Clearwing Borer

Podosesia aureocincta

Adults emerge in May and June

Ash/Lilac Borer

Podosesia syringae

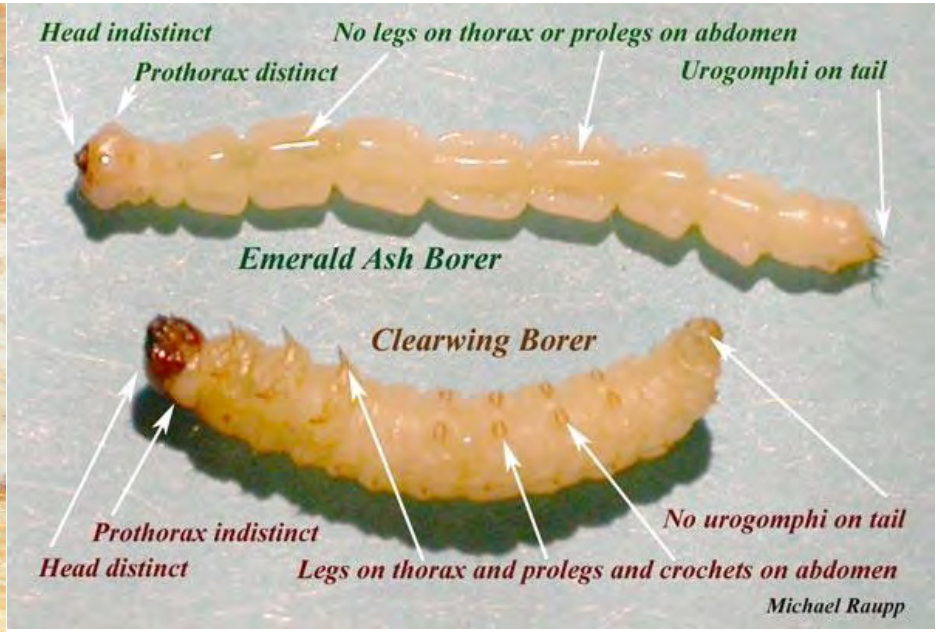
Emerald Ash Borer | Native Insects and Look-Alike Damage

for Master Gardeners

Clearwing Borers: *Larvae*

David Cappaert, Michigan State University, Bugwood.org

A clearwing borer larva feeding on ash phloem



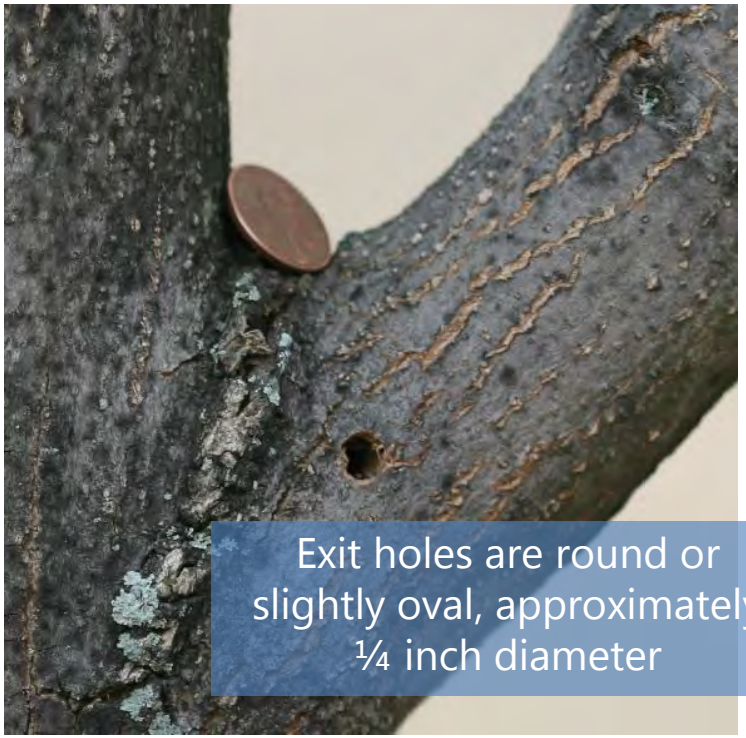
Clearwing borer larvae are caterpillars. They have three sets of legs on the front of their bodies, and prolegs on their abdomens. EAB larvae are completely legless!

Emerald Ash Borer | Native Insects and Look-Alike Damage

for Master Gardeners

Clearwing Borers: *Larval Damage*

Paper-like pupal skins protruding from exit holes are tell-tale signs of clearwing borer infestation



Exit holes are round or slightly oval, approximately ¼ inch diameter

Whitney Cranshaw, bugwood.org

Emerald Ash Borer | Native Insects and Look-Alike Damage

for Master Gardeners

Clearwing Borers: *Larval Damage*

Females often lay eggs close to pruning wounds. Collection of sawdust-like excrement (frass) indicates larval presence.

Frass pitched from borer holes may collect in crotches or around the tree's base.

Emerald Ash Borer | Native Insects and Look-Alike Damage

for Master Gardeners

Carpenterworm: *Adults*

- Can attack ash, elm, poplar, maple, willow, black locust, and cottonwood
- Life cycle takes 1-4 years to complete, depending on host and latitude
- Adults emerge May through June and lay eggs on stressed trees
- Adult males are smaller and have orange hindwings

An adult female carpenterworm moth

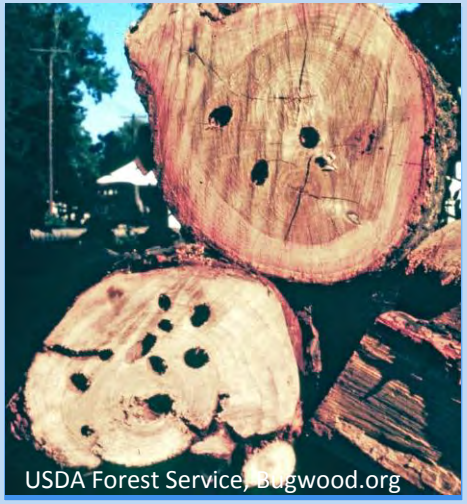
Photo: Cliff Sadof, Purdue University

Emerald Ash Borer | Native Insects and Look-Alike Damage

for Master Gardeners

Carpenterworm: *Larvae*

- Larvae bore deep into the heartwood, and pitch frass from their open tunnels
- They pupate close to the tunnel entrance and pupal shells are often visible.



Tunnels created by the large caterpillars can cause structural weakness

Emerald Ash Borer | Native Insects and Look-Alike Damage

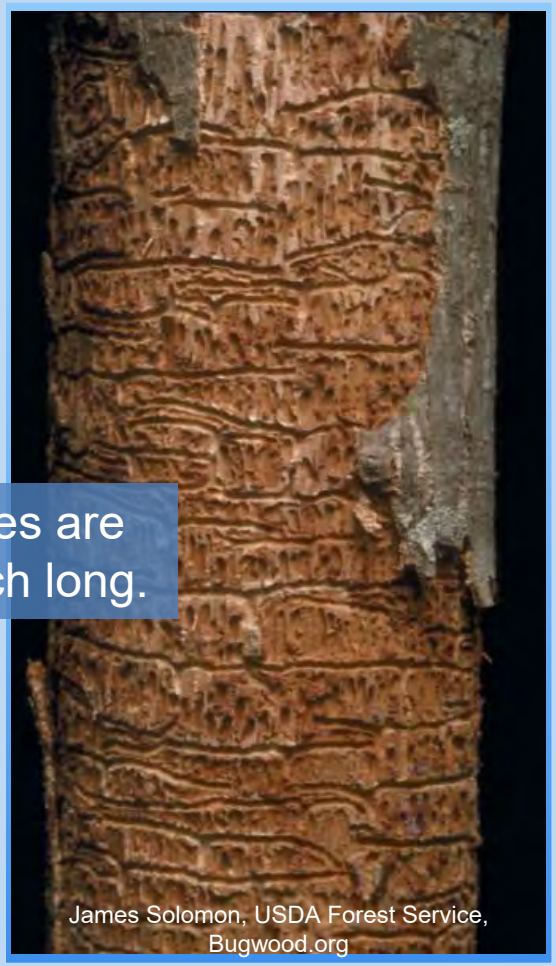
for Master Gardeners

Ash Bark Beetle

- Attack and breed in weakened, felled, and storm-damaged ash trees
- Larvae cause damage by tunneling in the inner bark and sapwood
- Unlike other borers, *adult* bark beetles also tunnel under bark to feed and reproduce
- Larval galleries radiate outward from the egg gallery. The bark may be peppered with tiny round exit holes

David Cappaert, Michigan State University, Bugwood.org

These tiny beetles are only about 1/8 inch long.



James Solomon, USDA Forest Service, Bugwood.org

Emerald Ash Borer | Native Insects and Look-Alike Damage

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Ash mortality caused by EAB may force local extinction of native borers and other insects that depend on ash trees for survival.

At risk:

- **43 native arthropod species** depend solely on ash
- **An additional 30 arthropod species** have only one or two other host plants
- **Cascading, long-term ecological effects** of EAB are likely but their extent is currently unknown

Ash weevils (top two photos), Blackheaded ash sawflies (center), and ash midrib-gall midges (bottom) are threatened with extinction.

Emerald Ash Borer | Native Insects and Look-Alike Damage

for Master Gardeners

Common Diseases of Ash

Some common pathogens of American ash trees produce canopy symptoms that may resemble EAB damage.

Ash Yellows is caused by a microscopic organism called a phytoplasma, which clogs the tree's vascular tissue.

- Formation of witches' brooms is common
- This is followed by decline and death of branches
- Organism also causes witches' brooms in lilac
- There is no known cure

William Jacobi, Colorado State University, Bugwood.org

Emerald Ash Borer | Native Insects and Look-Alike Damage

for Master Gardeners

Common Diseases of Ash

Some common pathogens of American ash trees produce canopy symptoms that may resemble EAB damage.

Ash Anthracnose is caused by a fungus that leads to a condition called 'leaf blight'.

- Infected leaves can fall in great number, covering sidewalks and yards.
- Dead tissue is most noticeable along leaf veins or at leaf edges where moisture lingers.
- Defoliation may be extensive, but with good maintenance, the tree has a good chance of survival.

Emerald Ash Borer | Native Insects and Look-Alike Damage

for Master Gardeners

Common Diseases of Ash

Some common pathogens of American ash trees produce canopy symptoms that may resemble EAB damage.

P&PDL, Purdue University

Verticillium Wilt is caused by soil-borne fungi that attack and block the tree's vascular system.

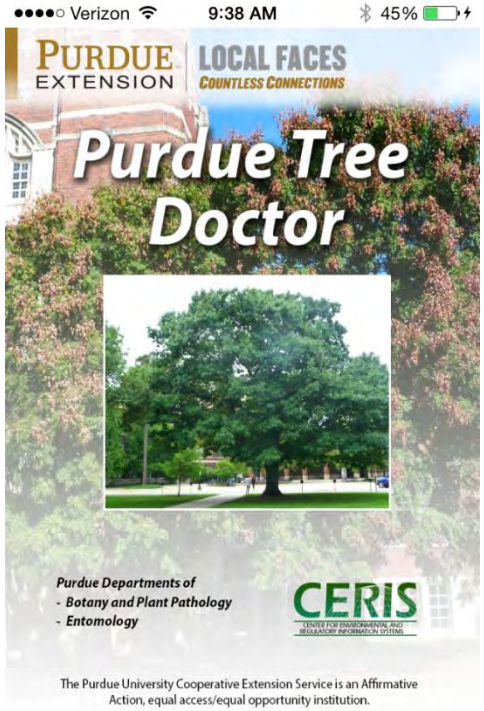
- Wilting of leaves on individual branches, or on one side of the tree is common
- Leaf margins yellow, then brown, may dry out completely by mid-summer.
- Fungi persist in soil for many years, so replace dead plants with resistant species.

University of Illinois IPM Program

Emerald Ash Borer | Native Insects and Look-Alike Damage

for Master Gardeners

Get The Purdue Tree Doctor Smartphone App And Confirm Your Diagnosis



Purdueplantdoctor.com
Or in the app store

Emerald Ash Borer | Course Overview

for Master Gardeners

- EAB Background
- Signs and Symptoms
- **To Treat or Not to Treat?**
- Insecticide Options
- Biological Control

To Treat or Not to Treat?

When it comes to managing ash trees in the face of EAB, you have two options: cut them down, or treat them.

Learn:

- The value of trees
- Biology of treatment
- Right tree, right place—Assessing treatment candidacy
- Invasion wave and duration of treatment

Emerald Ash Borer | To Treat or Not To Treat?

for Master Gardeners

The Cost of Treatment

Treating all ash trees wooded or forested areas is cost prohibitive. However, in the built environment, where loss of environmental services and removal costs are a consideration, treatment of some healthy, high-values trees is a cost-effective management tool. See the section on EAB Cost Calculators to weigh the tradeoffs.

Treatment Overview

Since EAB's discovery in 2002, a great deal has been learned about how to manage it. Protection of certain ash trees with properly applied insecticide treatments is now viewed as a reliable and useful component in an integrated EAB management plan. Insecticides proven by research to be most effective against EAB are systemic treatments.

There are two general ways treatment is currently being used as a management tool:

- To preserve high value ash trees for the duration of their service lives
- To temporarily delay mortality of ash trees to stage removals and allow establishment of replacement trees

Emerald Ash Borer | To Treat or Not To Treat?

for Master Gardeners

Healthy Trees Have Value

Most people can agree that trees make our built environment more livable and provide aesthetic value. Trees also:

The urban forest in Indianapolis provided over $6.6 million in benefits in 2008.

- **Improve air quality and human health** by storing carbon, releasing O_2, intercepting particulates, and reducing noise pollution and ozone.
- **Reduce storm water runoff** and absorb pollutants from soil.
- **Reduce energy costs** by shading in summer and shielding in winter, and reduce urban heat island effects.

Emerald Ash Borer | To Treat or Not To Treat?

for Master Gardeners

Healthy Trees Have Value!

National Tree Benefit Calculator

Beta

Thank you for choosing this site to calculate the economic and ecological benefits of your tree.

Want a useful tool for demonstrating the value of clients' trees? See for yourself!

www.treebenefits.com/calculator/

Example: What are the benefits of a 20" ash in Lafayette, IN?

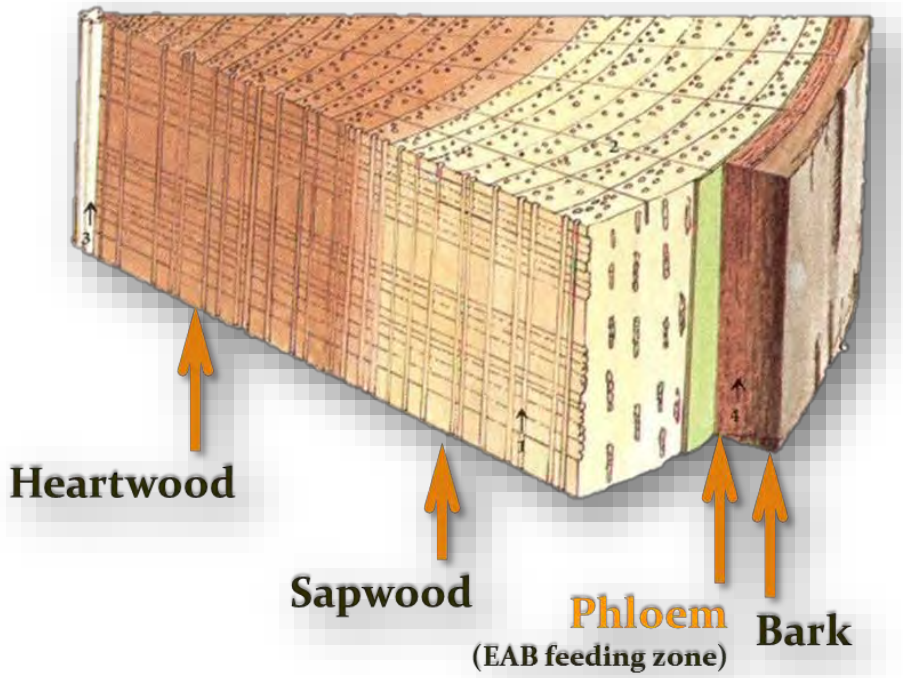
Emerald Ash Borer | To Treat or Not To Treat?

for Master Gardeners

Biology of Treatment

A tree needs a healthy vascular system to transport systemic insecticides.

- All treatments work best BEFORE the tree is already infested.
- A tree that has already been damaged by EAB requires a stronger treatment.
- The tree must be actively transpiring to effectively transport systemic products



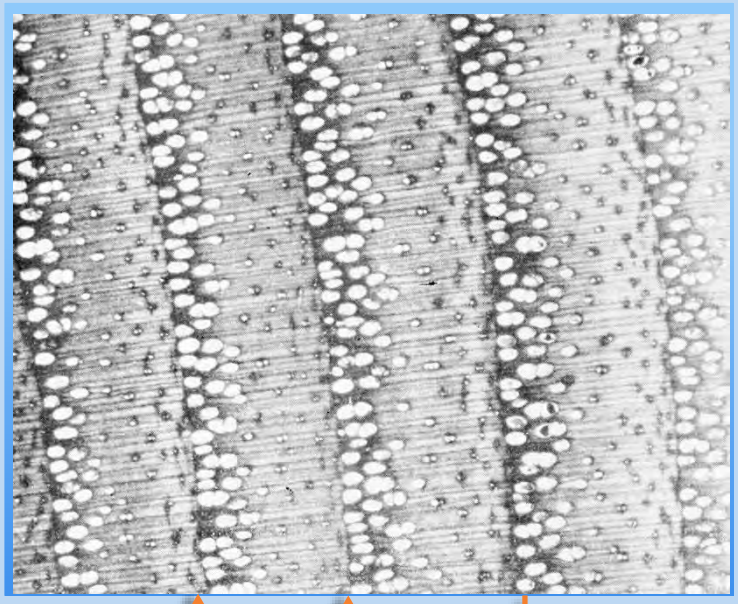
Sys•tem•ic:

Entering the plant through roots or stem and passing through the vascular system to other tissues

Insecticides kill EAB adults that feed on leaves before egg laying. Larvae are killed as they hatch from eggs laid on the bark.

Emerald Ash Borer | To Treat or Not To Treat?

for Master Gardeners



Biology of Treatment

Ash trees are **ring-porous,** which means that their active xylem vessels are relatively large and concentrated in a single layer under the bark. This characteristic makes ash trees especially vulnerable to attack by EAB larvae, which feed on phloem tissue directly under the bark and eventually damage the single functional xylem ring as they grow.

The vascular systems of **diffuse-porous** trees, such as birch (left), are characterized by vessels spread evenly throughout the sapwood. This means water is carried by several of the xylem rings.

Emerald Ash Borer | To Treat or Not To Treat?

for Master Gardeners

How Much is too Much

The amount of canopy decline present at the time of treatment is often used as an indication of tree health. Treatment effectiveness drops off rapidly on trees that have already lost **30% or more** of their canopy. These trees are usually better to remove than treat.

Assessing Treatment Candidacy

Not every ash tree can or should be protected with insecticides

Research has shown that initial health of a treated tree is a primary determining factor in whether or not treatment works. Another concern is tree interaction with infrastructure, such as sidewalks and powerlines, and removal may be a way to correct past planting mistakes.

When assessing treatment candidacy, some questions you should ask are:

- Is the tree healthy and growing vigorously?
- Is the tree planted in the proper site?
- Is the tree valuable to the owner?

Emerald Ash Borer | To Treat or Not To Treat?

for Master Gardeners

Unhealthy Trees:

Don't invest your client's management dollars into a tree that probably won't survive anyway.

- An unhealthy ash tree is not a good candidate for preventative OR curative treatment with insecticides.
- A vigorous vascular system is needed to effectively distribute insecticide through the tree.

This ash tree is not a good candidate for insecticide treatment

Emerald Ash Borer | To Treat or Not To Treat?

for Master Gardeners

Improper Siting:

Don't invest your client's management dollars in a permanent maintenance problem.

- Trees in poor (or the wrong) sites should not be protected from EAB.
- For example, trees located under power lines will require maintenance to keep them clear of wires.

Many utility companies have adopted a removal policy for ash trees interfering with lines.

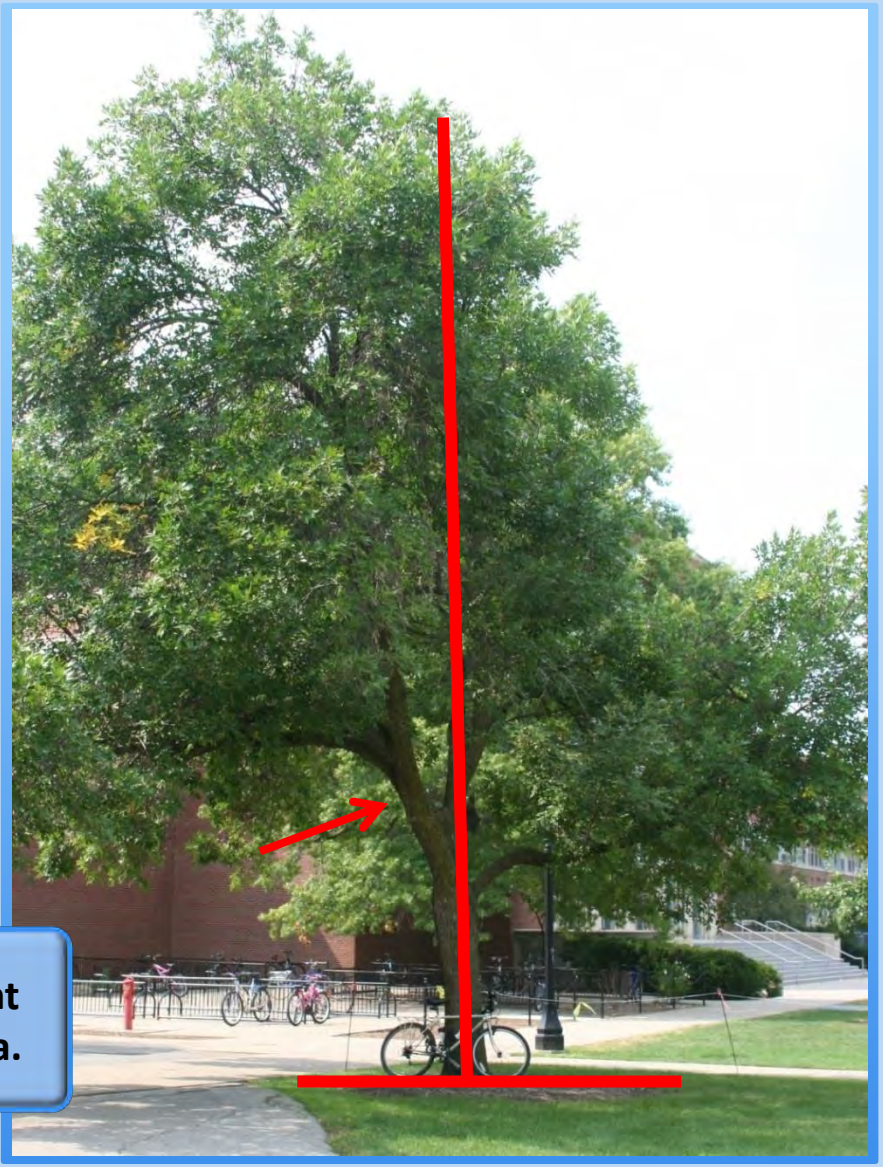
Emerald Ash Borer | To Treat or Not To Treat?

for Master Gardeners

Structural Defects:

Don't invest your client's management dollars in a hazard tree.

- This tree has more than ¾ of its weight leaning above a heavily trafficked area.
- Unbalanced trees or those with structural defects are hazards when they may fall onto people or property.



This tree has more than ¾ of its weight leaning above a heavily trafficked area.

Emerald Ash Borer | To Treat or Not To Treat?

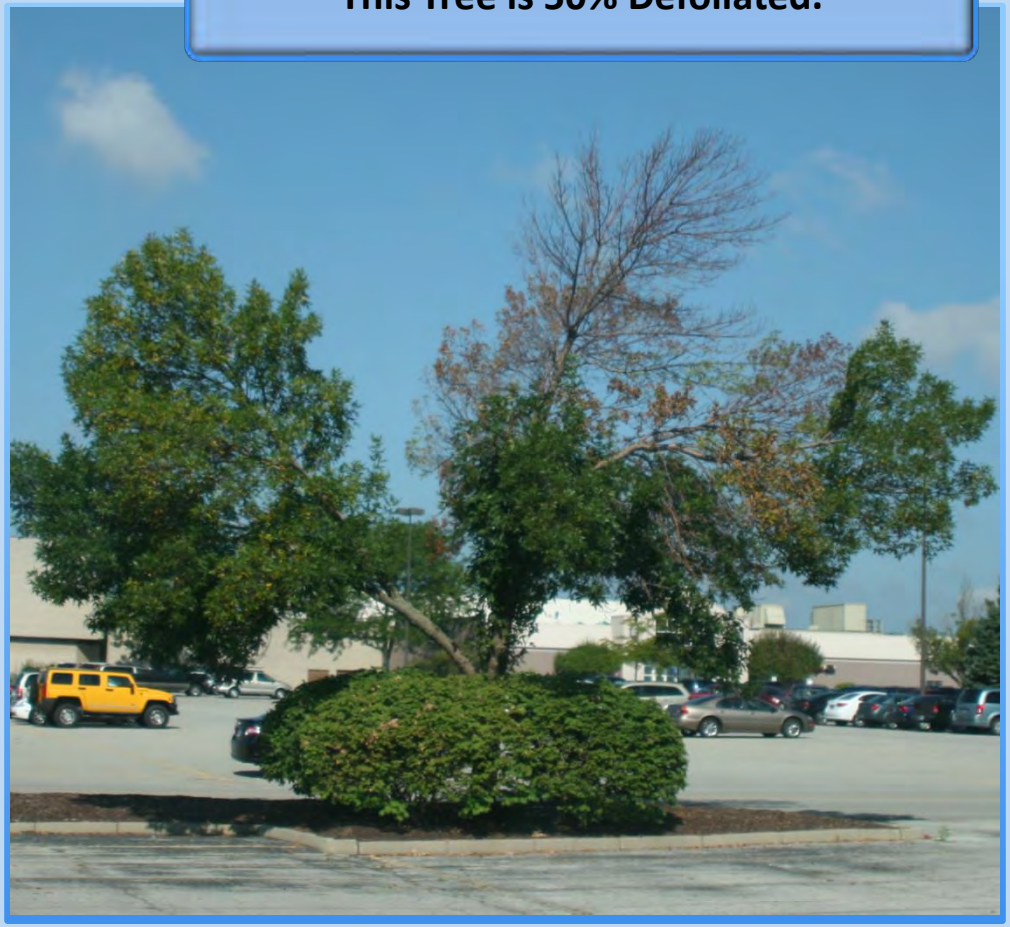
for Master Gardeners

Structural Defects:

Don't invest your client's management dollars into a tree whose living parts are not worth saving.

- If a treatment candidate is already experiencing dieback, keep in mind what the remaining structure will be.
- The living part of the tree is too distorted and asymmetrical to be worth saving.

This Tree is 50% Defoliated.



Emerald Ash Borer | To Treat or Not To Treat?

for Master Gardeners

Defoliation:

Treatment should only be attempted for trees with up to 30% defoliation. Don't invest your client's management dollars into a tree that won't survive anyway.

Treatable

This tree has lost 10% of its canopy. It may still be healthy enough for treatment.

This tree has lost 20% of its canopy.

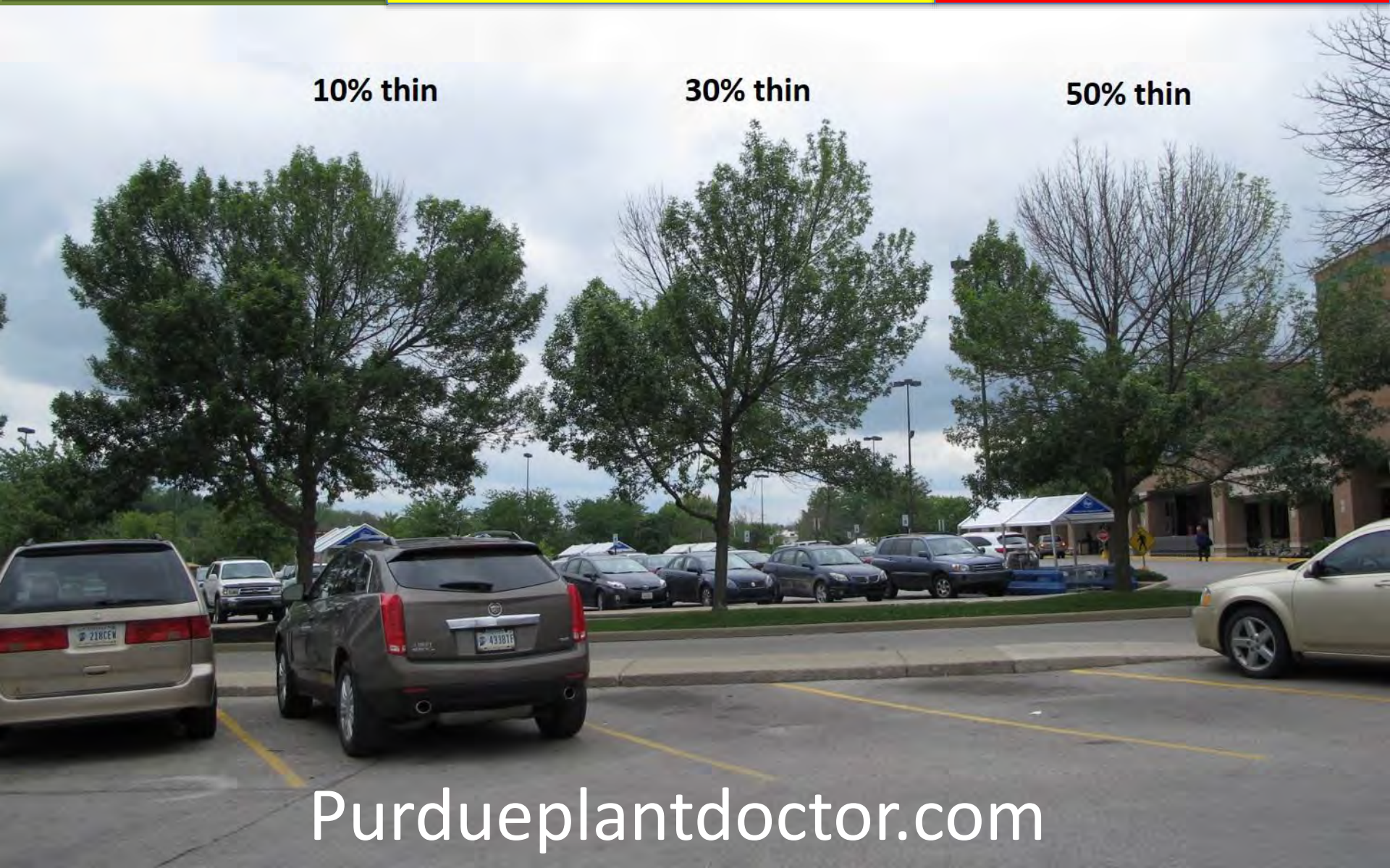
Not Treatable

This tree has lost 60% of its canopy. Treatment efficacy is unlikely.

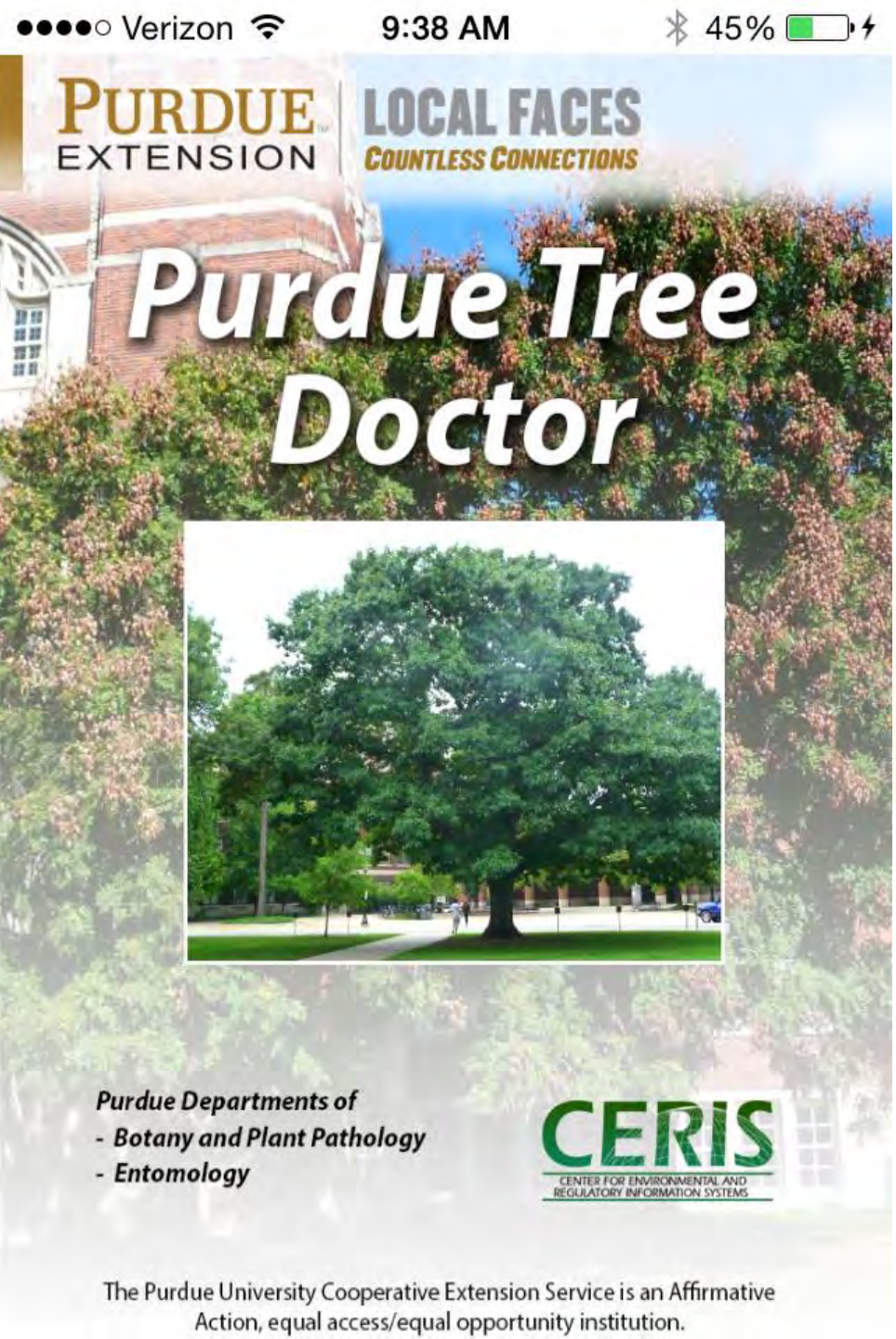
This tree is 100% defoliated. Remaining leaves are borne on epicormic shoots.

Trees with > 30% thining are NOT worth saving!

Good < 10%	Fair > 10% and ≤ 30%	Poor or worse > 30% thinning



Purdueplantdoctor.com



Use the Purdue Tree Doctor to estimate canopy thinning

Purdueplantdoctor.com

Emerald Ash Borer | To Treat or Not To Treat?

for Master Gardeners

HEALTHY TREES!

This tree has 100% of its canopy, has plenty of space to grow, and adds shading and aesthetic value to this parking lot.

It is a good treatment candidate.

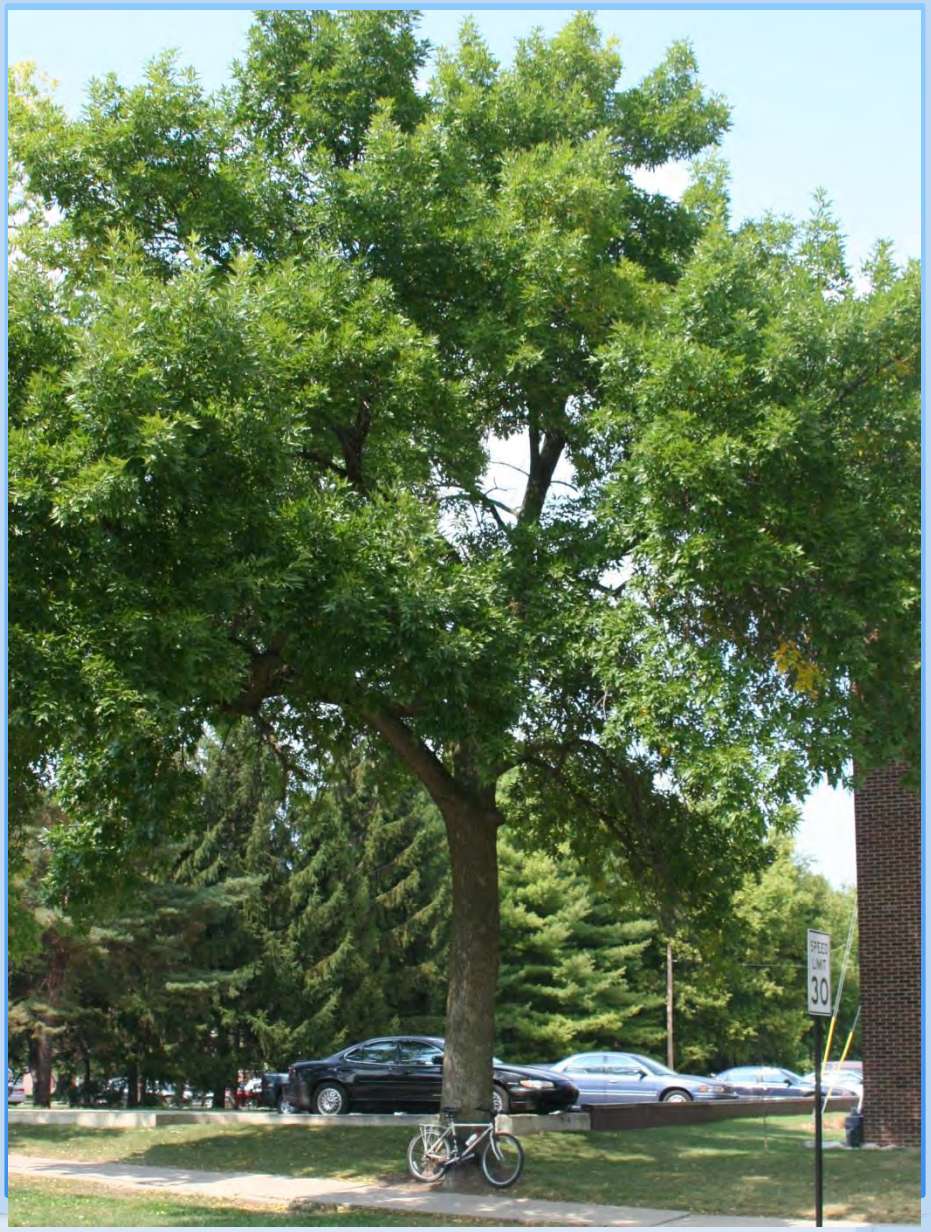
Emerald Ash Borer | To Treat or Not To Treat?

for Master Gardeners

HEALTHY TREES!

This large ash tree is healthy and provides shading to the adjacent building and sidewalk.

It is a good treatment candidate.



Emerald Ash Borer | To Treat or Not To Treat?

for Master Gardeners

The character of this street lined with healthy ash trees will change dramatically if the trees are lost.

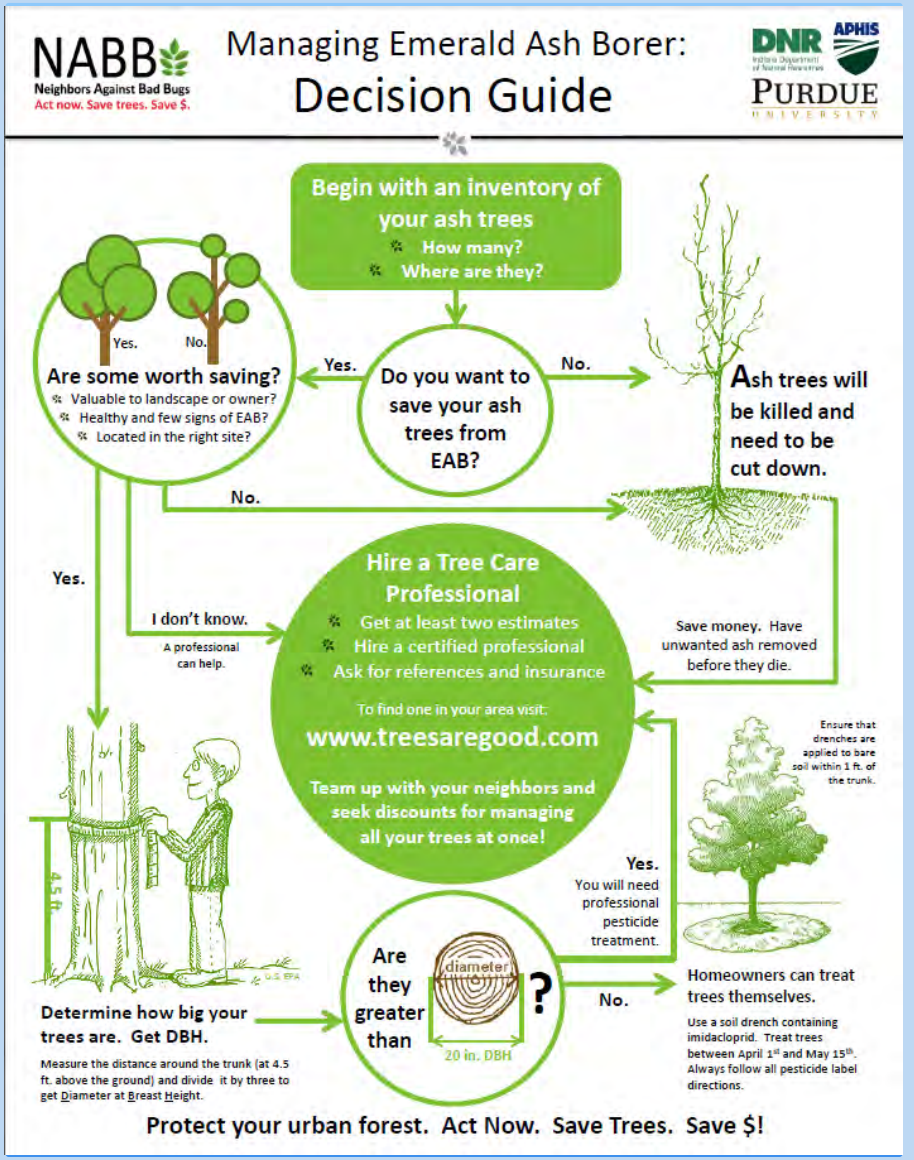
Emerald Ash Borer | To Treat or Not To Treat?

for Master Gardeners

The Managing EAB Decision Guide

This new decision guide can help you communicate with your customers, and aid them in making decisions about their ash trees. Download it for FREE and pass it along:

NABB Decision Guide



Measuring Tree Size

Treatment recommendations are based on the **tree's** DBH, or Diameter at Breast Height.

To get DBH:

1. Measure the distance around the trunk (circumference) at breast height (4.5ft from the ground).
2. Divide that number by 3 to get diameter.

Example: If the distance around the trunk is 30 inches, the DBH is roughly 10 inches (30 inches divided by 3).

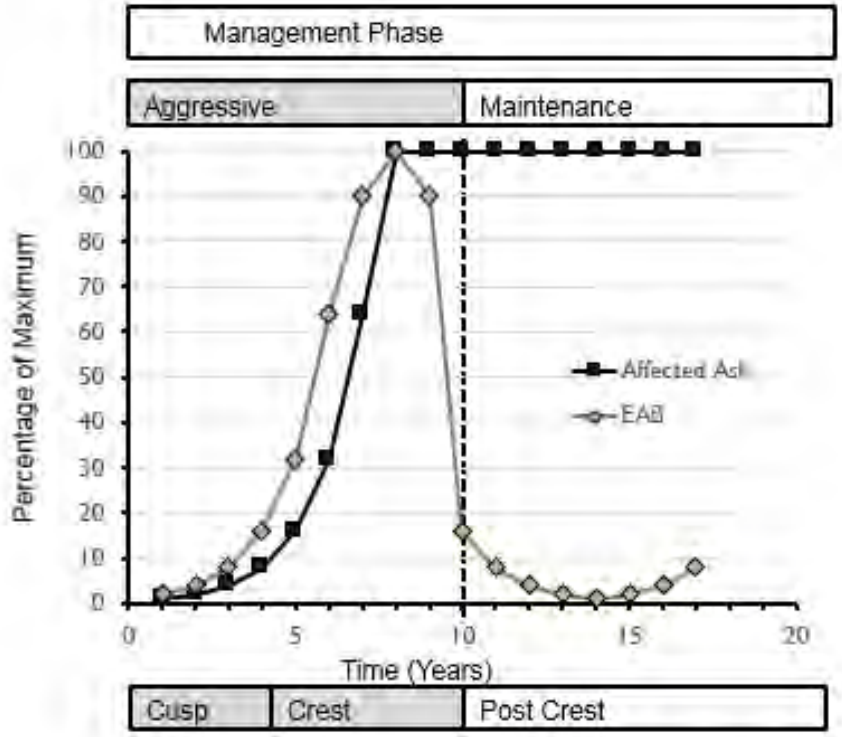
Emerald Ash Borer | To Treat or Not To Treat?

for Master Gardeners

The EAB Invasion Wave

Treatment needs fluctuate as EAB populations in your area change.

- CUSP- Few trees die as EAB population builds.
- CREST- Tree death and EAB population increase sharply. Treatment must be AGGRESSIVE.
- POST CREST- After ALL untreated trees are dead EAB populations and need for treatment declines. MAINTAIN trees by treating only when new damage is found.



Protection needs and populations waves of EAB and dying ash trees

Emerald Ash Borer | To Treat or Not To Treat?

for Master Gardeners

The EAB Invasion Wave and Treatment Duration

A treated ash tree weathers the EAB invasion wave, while its untreated neighbor across the street succumbs.

- **Treated trees need to be protected for the rest of their lives.**
- **You will need to treat trees yearly (or every 3 years for some products) for 10 years after the first ash trees in the area start dying.** The size of EAB populations in your area will increase until the insects run out of living, untreated ash trees. Then EAB will either die or fly away in search of live trees.
- **After all untreated ash trees in the area die, you can likely reduce how often you treat surviving trees.** The remaining beetles may take several years to build up to damaging numbers again.
- **Inspect trees annually for symptoms and treat when found.**

Emerald Ash Borer | To Treat or Not To Treat?

for Master Gardeners

Sometimes trees can look worse the year following treatment. This is common if the tree was already infested or if beetle densities in the area are high. Continue with properly applied treatment, and trees generally begin to recover in the second year.

The EAB "Bunker"

A good way to conceptualize treatment is that you are creating a protective "bunker" for the ash tree as the tidal wave of EAB moves through the area. The bunker must be very strong during the peak of the invasion, when pest pressure on the trees is high.

The optimal time to begin treating is when EAB is found within 15 miles of your trees.

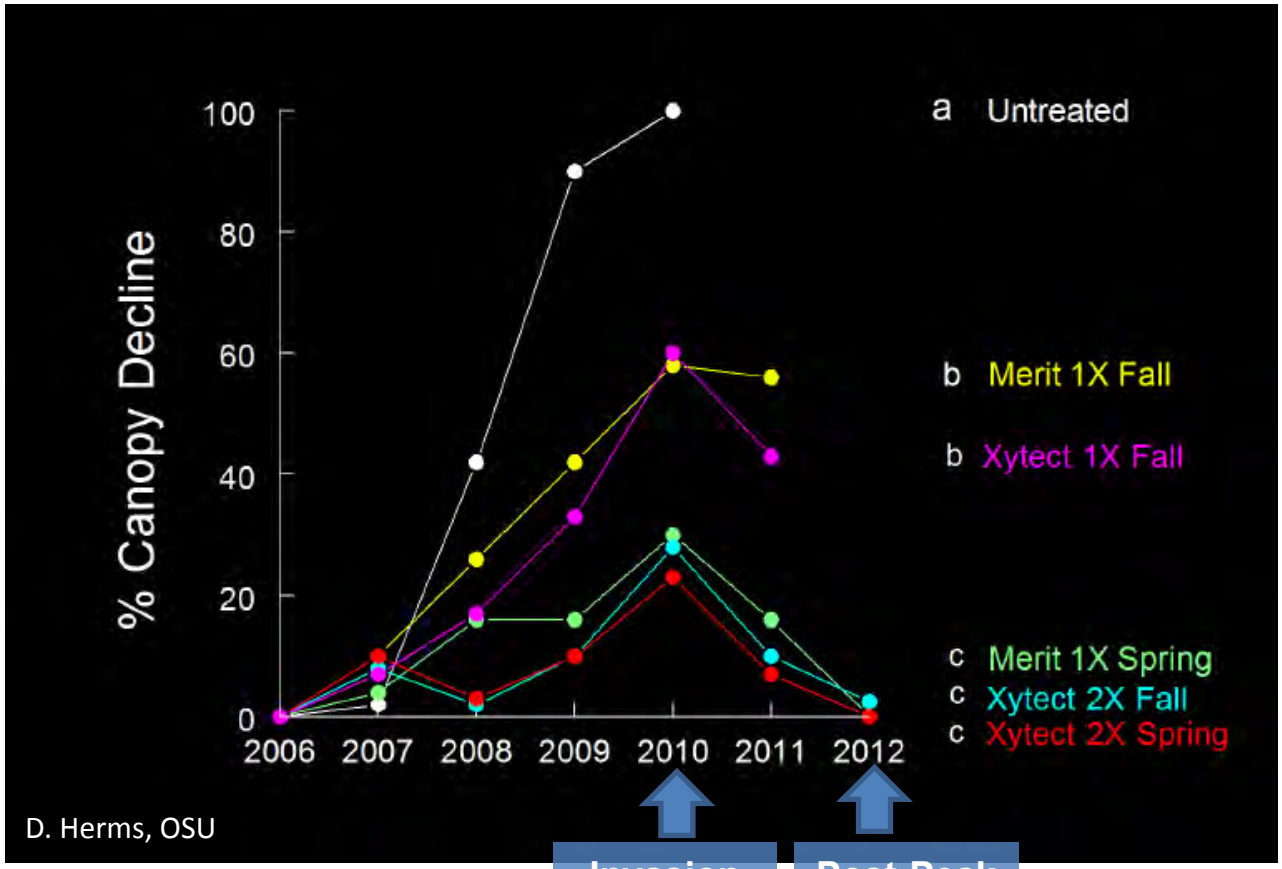
Emerald Ash Borer | To Treat or Not To Treat?

for Master Gardeners

Annual Imidacloprid Soil Drenches (14-20" DBH)

This study by Dan Herms of The Ohio State University demonstrates how trees with a DBH of 14 to 20" can be protected with annual spring applications of imidacloprid (Merit or Xytect) each year. A double rate (2X) is needed to achieve protection with a fall application. Note how these three applications (c) treated annually with insecticide may still experience 30% defoliation during the peak of the invasion wave (2010). Eventually (2012), trees recover.

The Effect of Pest Pressure



Emerald Ash Borer | To Treat or Not To Treat?

for Master Gardeners

Removals

It is always best to remove ash trees BEFORE they are completely killed by EAB. Because larval feeding cuts off nutrient and water flow, infested trees dry out and become very brittle. Ash trees killed by EAB are extremely dangerous to climb, and tend to shatter during removal. Standing dead ash are also a serious public health hazard.

In areas inaccessible to bucket trucks, such as cemeteries and parks, removal of standing dead trees is a serious (and costly) issue.

Emerald Ash Borer | Course Overview

for Master Gardeners

- EAB Background
- Signs and Symptoms
- To Treat or Not to Treat?
- **Insecticide Options**
- Biological Control

Insecticide Options

Learn how **tree size, tree condition,** and **time of year** affect insecticide treatment options.

Learn specifics on current delivery methods, effective products, dose recommendations, and per acre limits.

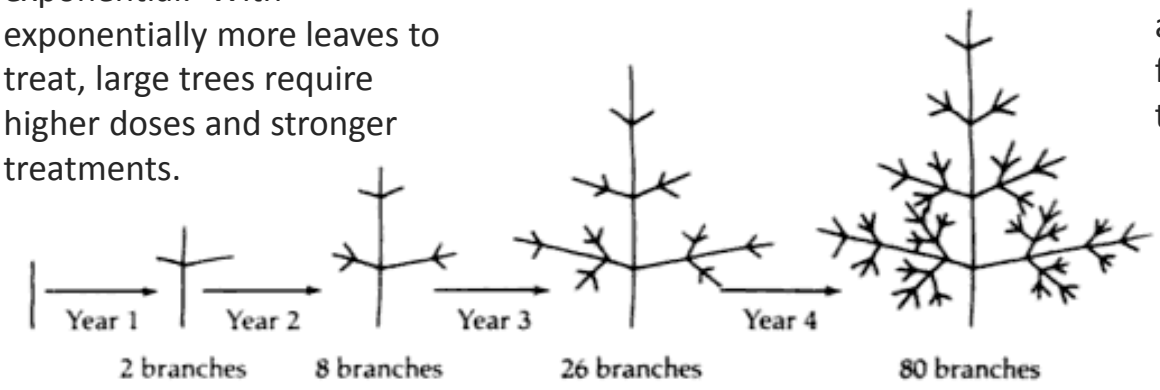
Emerald Ash Borer | Insecticide Options

for Master Gardeners

Factors Affecting Treatment Decisions

Tree Size

As trees grow, they need more and more photosynthate to sustain themselves. While trees add girth in a linear fashion, the addition of leaves and branches is almost exponential. With exponentially more leaves to treat, large trees require higher doses and stronger treatments.



Tree Condition

Trees with damaged vascular systems have reduced insecticide transport capacity, and require stronger treatments.

Time of Year

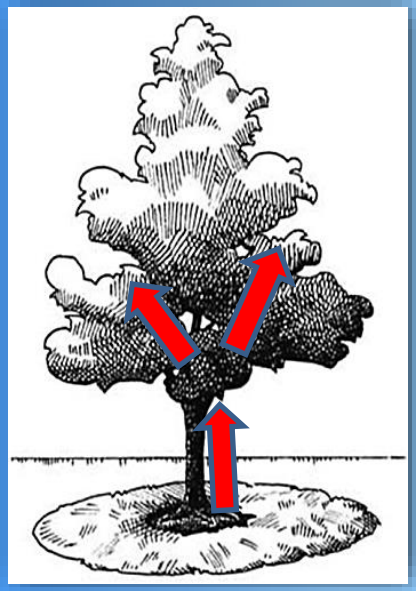
Trees must be actively transpiring at the time of treatment in order to distribute the insecticide. Ideally, the insecticide should reach the leaves in time to kill feeding adults and hatching larvae in the early spring. Some active ingredients are transported faster in the tree, allowing them to be applied later in the year.

As a tree grows, it adds branches and leaves in an exponential fashion.
Figure from The Growing Tree by Brayton F. Wilson.

Emerald Ash Borer | Insecticide Options

for Master Gardeners

All Systemics Need Water!



Adequate irrigation, both before **AND AFTER** treatment is beneficial, especially in dry conditions. Water carries the insecticide from the treatment site to the canopy.

Systemic Insecticides Overview

Many active ingredients and delivery methods have been tested against EAB. The treatments that follow have been proven effective at preserving ash trees in independent university research trials and in practice. In order to select the most appropriate treatment one must consider the **size of the treated tree, tree condition,** and **time of year.**

Active Ingredients

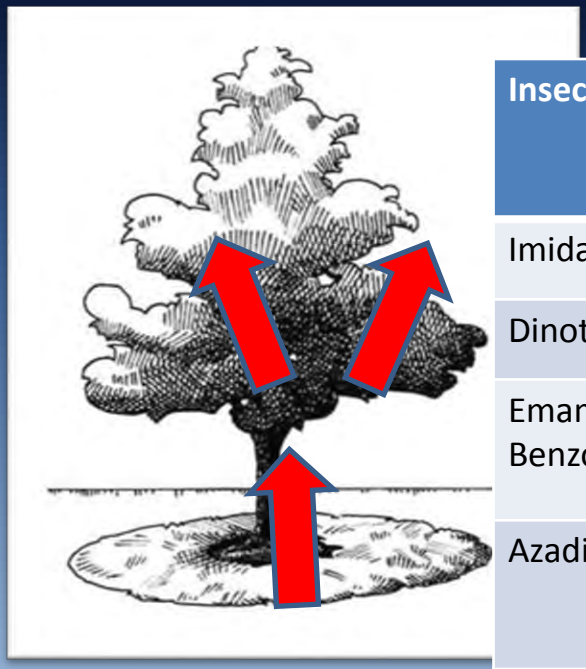
- **Azadirachtin**
- **Imidacloprid**
- **Dinotefuran**
- **Emamectin benzoate**

Delivery Methods

- **Soil injections and soil drenches**
- **Basal trunk sprays**
- **Trunk injections**

Emerald Ash Borer | Toxicity of Different Pesticides

for Master Gardeners



Insecticide	Egg	Larvae				Toxicity of Poisoned Leaves to adults
		L1	L2	L3	L4	
Imidacloprid	No	Yes	Yes	No	No	Sustained feeding
Dinotefuran	No	Yes	Yes	No	No	A few bites
Emamectin Benzoate	No	Yes	Yes	Yes	Yes	One or two bites
Azadirachtin	No	Yes	Yes	Yes	Yes	Not toxic, but reduces fecundity of adults

Water carries the pesticide

Not every pesticide kills all larvae

Emerald Ash Borer | Summary of Insecticide Options

for Master Gardeners

Product	Time of Year	Other Considerations[ab]
Imidacloprid	Spring (early April to mid-May) Fall (October to November)	Spring treatments more effective than those in fall (up to 20") No More than 128" DBH of tree can be treated per acre at 1x rate
Dinotefuran	Spring (early May to mid-June)	Soil injection or trunk sprays equally effective **up to 25" DBH** No More than 104" DBH of tree can be treated per acre
Emamectin benzoate	Bud-break to mid-June Mid-Summer to Fall color	Spring applications kill adults before eggs are laid this year. Fall applications kill next year's adult beetles as well as some larvae **(no size restrictions)** **No per acre restrictions**
Azadirachtin	Bud break to end of June	To be applied every other year until peak of EAB then should be applied annually **No per acre restrictions**

[a] Applications are timed so that enough insecticide is in the leaves to kill EAB adults that feed on leaves before they have laid most of their eggs

[b] Trees must be actively transpiring to take up these products

[c] Higher rates needed on trees > 15" DBH for Dinotefuran

Emerald Ash Borer | Insecticide Options

for Master Gardeners

Imidacloprid

Black locust tree in bloom

The optimal application time of imidacloprid is early spring, just after bud break. **The insecticide needs 4-6 weeks to migrate** from the application site to the leaves, where it is consumed by EAB adults, which emerge around the time of black locust bloom, usually in mid-May.

Imidacloprid is the most widely tested soil-applied systemic insecticide for EAB control. It is a neonicotinoid, which is a class of insect neurotoxins modeled after nicotine.

Delivery Method: Soil drench or injection, trunk injection

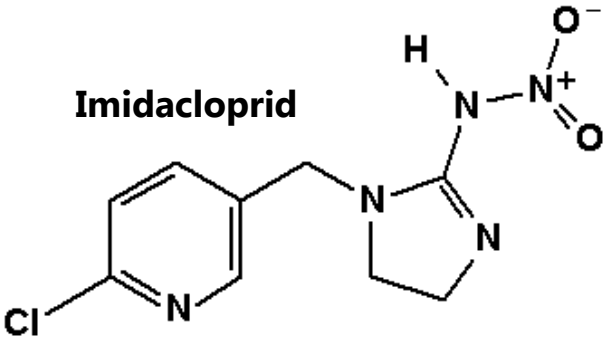
Trade Names: Merit ® (75WP, 75WSP, 2F), Xytect ™ (2F, 75WSP)

Size of Trees: Up to 20" DBH (Diameter at Breast Height)

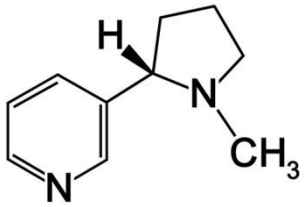
Time of Year: Spring (early April to mid-May), Fall (October to November

Frequency and Dosage : Annual; For spring treatments, apply 1.4 gm ai/in DBH, for fall treatments, apply 2.8 gm/in DBH

Imidacloprid



Nicotine



Emerald Ash Borer | Insecticide Options

for Master Gardeners

Dinotefuran

Like imidacloprid, dinotefuran is a neonicotinoid insecticide. Its' greater mobility within plant tissues allows later spring application times than imidacloprid and application via bark sprays.

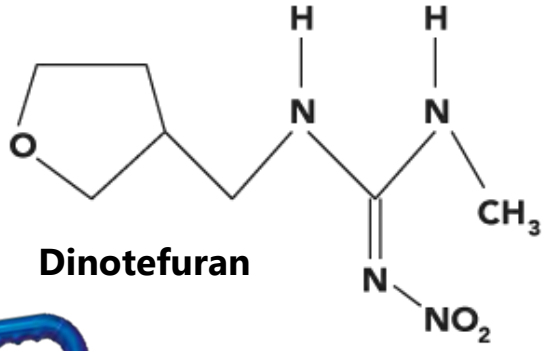
Delivery Method: Soil drench or injection, bark spray

Trade Names: Safari™ (20SG)

Size of Trees: Up to 12" DBH (Diameter at Breast Height)

Time of Year: Spring (early April to mid-June)

Frequency and Dosage: Annual; 1.5 gm ai/in DBH



Dinotefuran

Imidacloprid and dinotefuran are also available in homeowner formulations.

Emerald Ash Borer | Insecticide Options

for Master Gardeners

Per Acre Limits

Important Note

There are per-acre limits on how much imidacloprid and dinotefuran can be applied per year. Exceeding this dose is in violation of the label and may contaminate nearby ground water. Because these AI's are commonly used in turf pest control, it is important to inquire with your clients regarding previous treatments.

In Indiana, Ohio, and Michigan there is a special local needs label (24c) that allows a higher rate of imidacloprid to be applied per acre. When treating larger trees with imidacloprid at twice the rate you can only treat half the number of trees. Click below for a summary of current limits.

Indiana Per Acre Limits

Emerald Ash Borer | Insecticide Options

for Master Gardeners

Finding Label Use Restrictions

For outdoor ornamentals, broadcast applications cannot exceed a total of 1.6 pints (0.4 lb of active ingredient) per acre per year.

Ant Management Programs

Use MERIT 2F Insecticide to control aphids, scale insects, mealybugs and other sucking pests on

THIS IS PER ACRE MAXIMUM

RECOMMENDED APPLICATIONS - TREES, SHRUBS, FLOWERS AND GROUNDCOVERS

For use only in and around industrial and commercial buildings and residential areas, state, national, private wooded and forested areas for the insect pests listed below:

Adelgids	Flathead borers (including bronze birch and alder borer)	Leafhoppers (including glassy-winged sharpshooter)	Sawfly larvae
Aphids	Japanese beetles	Leafminers	Soft scales
Armored scales (suppression)	Lace bugs	Mealybugs	Thrips (suppression)
Black vine weevil larvae	Leaf beetles (including elm and viburnum leaf beetles)	Pine tip moth larvae	White grub larvae
Emerald ash borer		Psyllids	Whiteflies
Eucalyptus longhorned borer		Royal palm bugs	

TREES	0.1 to 0.2 fl. oz. (3 to 6 mL) per inch of trunk diameter (D.B.H.)

THIS IS THE LABELED RATE

Emerald Ash Borer | Insecticide Options

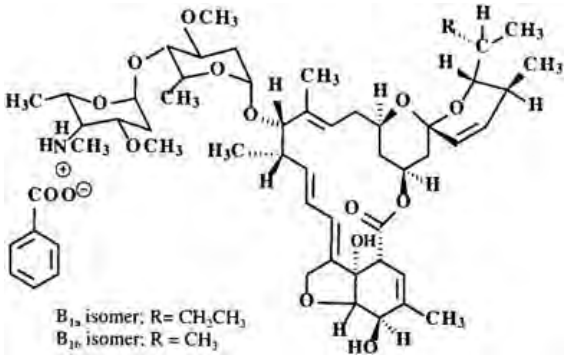
for Master Gardeners

Emamectin benzoate- Professionals Only

But what about the BIG trees?

Tree-äge injections can protect SMALL AND LARGE trees.

Provides the best control of EAB (up to 99%) of all products tested to date.
It moves rapidly through tree tissues and is currently recommended for large trees, trees with more defoliation, and areas with higher EAB densities.



Emamectin benzoate

Delivery Method: Trunk injection
Professionals only

Trade Names: Tree-äge®

Size of Trees: No restriction

Time of Year: Bud-break to mid-June is best for this year's beetles, but may be applied through August (Applications during summer drought can result in wilting and leaf drop)

Frequency and Dosage: Every 2 years; Based on tree size. See label for specifics.

Emerald Ash Borer | Insecticide Options

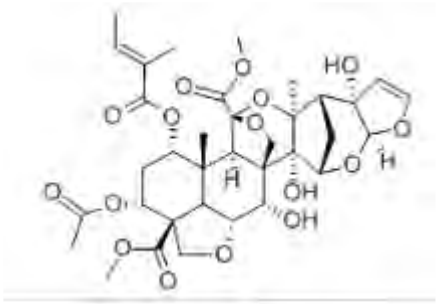
for Master Gardeners

Azadirachtin- Professionals Only

What about Organic Options?

Applications before symptoms are found is CRITICAL to successful use of this product.

This extract of the neem tree *Azadirachta indica* has been used successfully in Canada. Acts by killing larvae feeding in trunk. Does not kill adults. Females fed treated leaves lay fewer eggs.



Azadirachtin

Delivery Method: Trunk injection, Professionals only

Trade Names: Tree-Azin®

Size of Trees: No restriction

Time of Year: Bud-break to mid-June is best for this year's beetles,

Frequency and Dosage: Every 2 years until crest of EAB invasion, then yearly until crest has passed; Based on tree size. Must initiate treatments BEFORE SYMPTOMS occur for best results.

Emerald Ash Borer | Insecticide Options

for Master Gardeners

Delivery Methods

Instructional Video

Soil Drenches

- Imidacloprid binds to mulch and leaf litter, which can reduce uptake by the tree.
- Before applying soil drenches, it is important to remove, rake or pull away any mulch, dead leaves, or turf so the pesticide solution is poured directly on the soil.
- Fill a watering can or bucket partially full of water, put the measured amount of pesticide in next, and fill with more water to dilute.
- Apply product around the entire base of the tree. Don't apply it farther than a foot away from the trunk.

Apply soil drenches to moist but not very wet soils. Application to water-logged soil can result in excessive dilution or contamination of surface waters. Very dry soils also inhibit uptake. Be sure to water treated trees during a drought.

Emerald Ash Borer | Insecticide Options

for Master Gardeners

Delivery Methods

Soil Injections

Professionals Only

A pressurized system is used to deliver insecticide to tree roots beneath turf and mulch.

- Injections are made just beneath the soil surface (2-4 inches) within 18 inches of the trunk (where the density of fine roots is highest).
- This effectively bypasses turf, mulch on soil surface
- Soil injections help prevent runoff on sloped surfaces.
- Imidacloprid is recommended for trees up to 20” DBH

Emerald Ash Borer | Insecticide Options

for Master Gardeners

Delivery Methods

Basal Trunk Sprays

Professionals Only

- Dinotefuran is labeled for systemic bark spray application
- The lower 5 to 6 feet of the trunk is thoroughly coated just until run-off (about 1.5 fl oz per inch of DBH).
- Direct application to the trunk can speed uptake
- Kills adults feeding on leaves and young larvae feeding beneath bark

Dinotefuran is recommended for trees up to 18" DBH

Emerald Ash Borer | Insecticide Options

for Master Gardeners

Delivery Methods

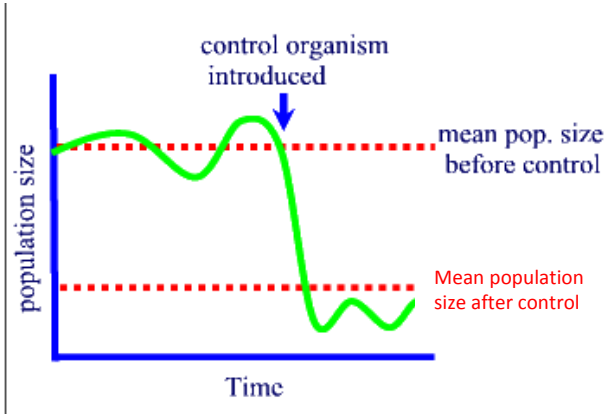
Trunk Injections *Professionals Only*

- Trunk injections are recommended for larger trees and those with more defoliation
- Emamectin benzoate is usually the active ingredient of choice
- Direct delivery inside the trunk is very effective and reduces potential for environmental contamination

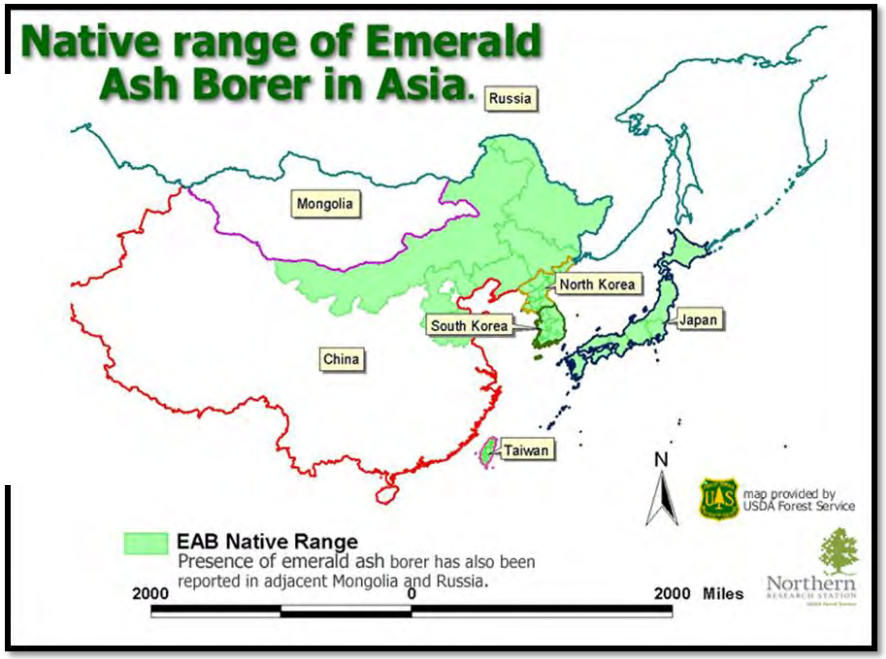
Several injection systems are available. Shown here are Arborjet's QUIK-jet and Tree IV systems.

Biological Control Rationale

- In EAB's natural environment, ash tree resistance and natural enemies keep its populations in check.
- In North America, EAB has few enemies and most ash trees have no resistance.
- Classic biological control (bio-control) involves returning to the pest's place of origin, finding natural enemies, and bringing them back to attack the pest.



Biological control reduces pest populations through introduction of natural enemies.



In 2003, scientists went to China to search for natural enemies of EAB.

Emerald Ash Borer | Course Overview

for Master Gardeners

EAB Background

Signs and Symptoms

To Treat or Not to Treat?

Insecticide Options

Biological Control

Biological Control

The use of living organisms to kill Emerald Ash Borer.

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Types of Natural Enemies

Parasitoids

Insects whose larvae live as parasites feeding on EAB, eventually killing it. Adult parasitoids live outside the EAB.

Predators

Directly consume EAB

Pathogens

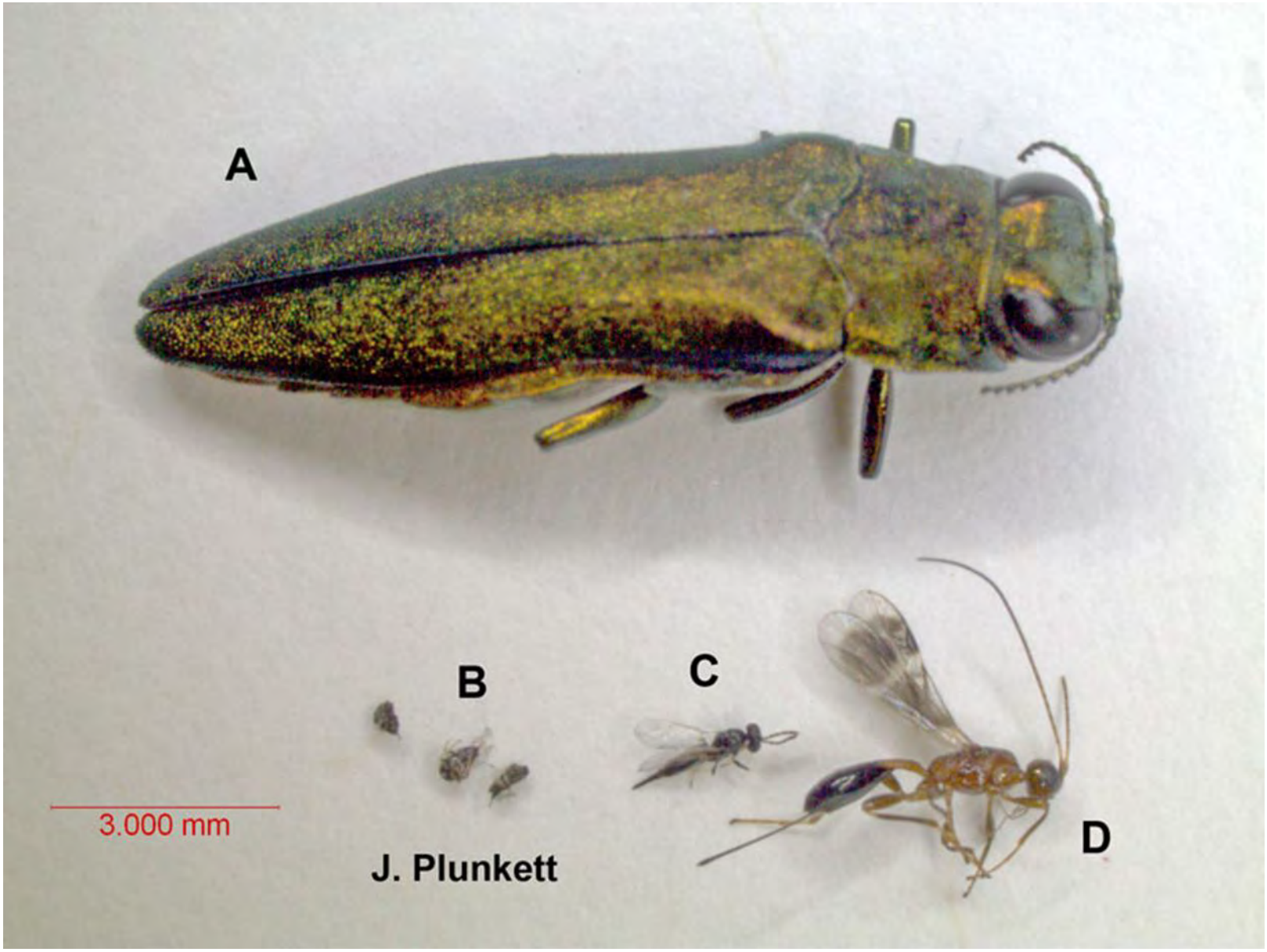
Certain fungi can infect EAB and kill the insect from the inside out. The fungus emerges from the dead insect and coats its body in spores.

Bio-control with Parasitoids

So far, parasitoids are the most effective bio-control for EAB

Dr. Cliff Sadof releases bio-control wasps on an ash tree in Indiana

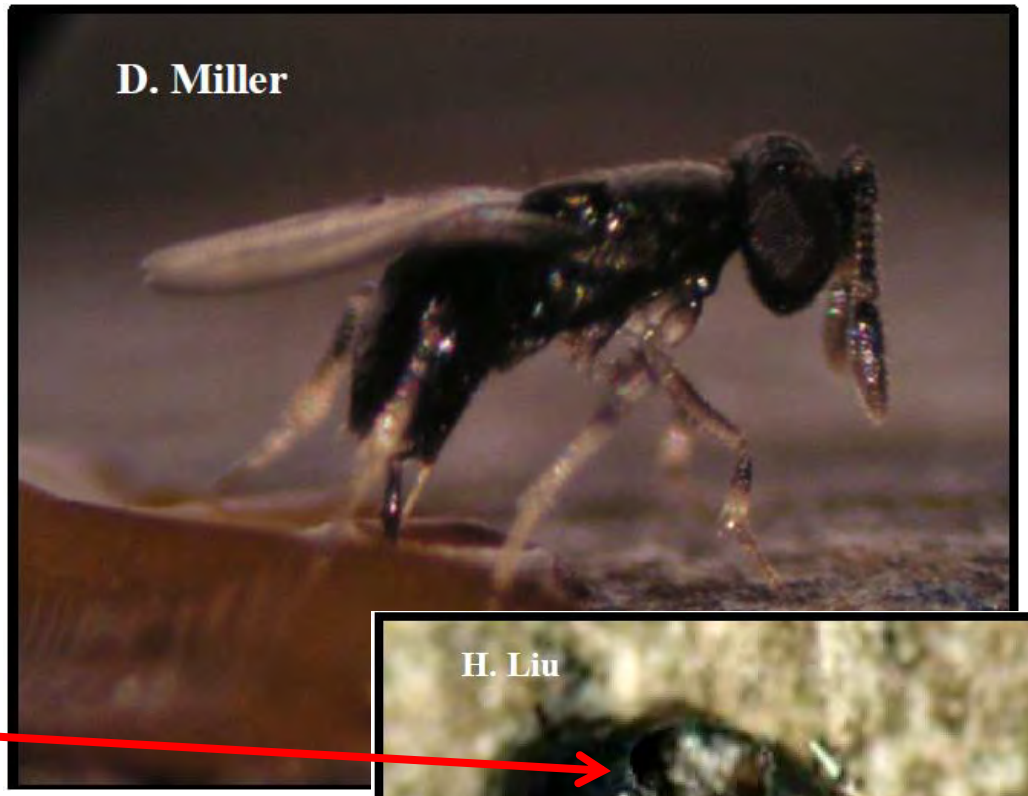
- A USDA-APHIS facility in Michigan produces three species of **non-stinging** parasitoid wasps for EAB bio-control
  - They do not harm humans or animals
  - They are from China
- They have been released in Michigan, Illinois, Indiana, Ohio, West Virginia, Maryland, and will be released in other states in the future.



An adult EAB (A), with three non-stinging bio-control wasps from China: (B) *Oobius agrili*, (C) *Tetrastichus planipennisi*, and (D) *Spathius agrili*

EAB Parasitoids: *Oobius agrili*

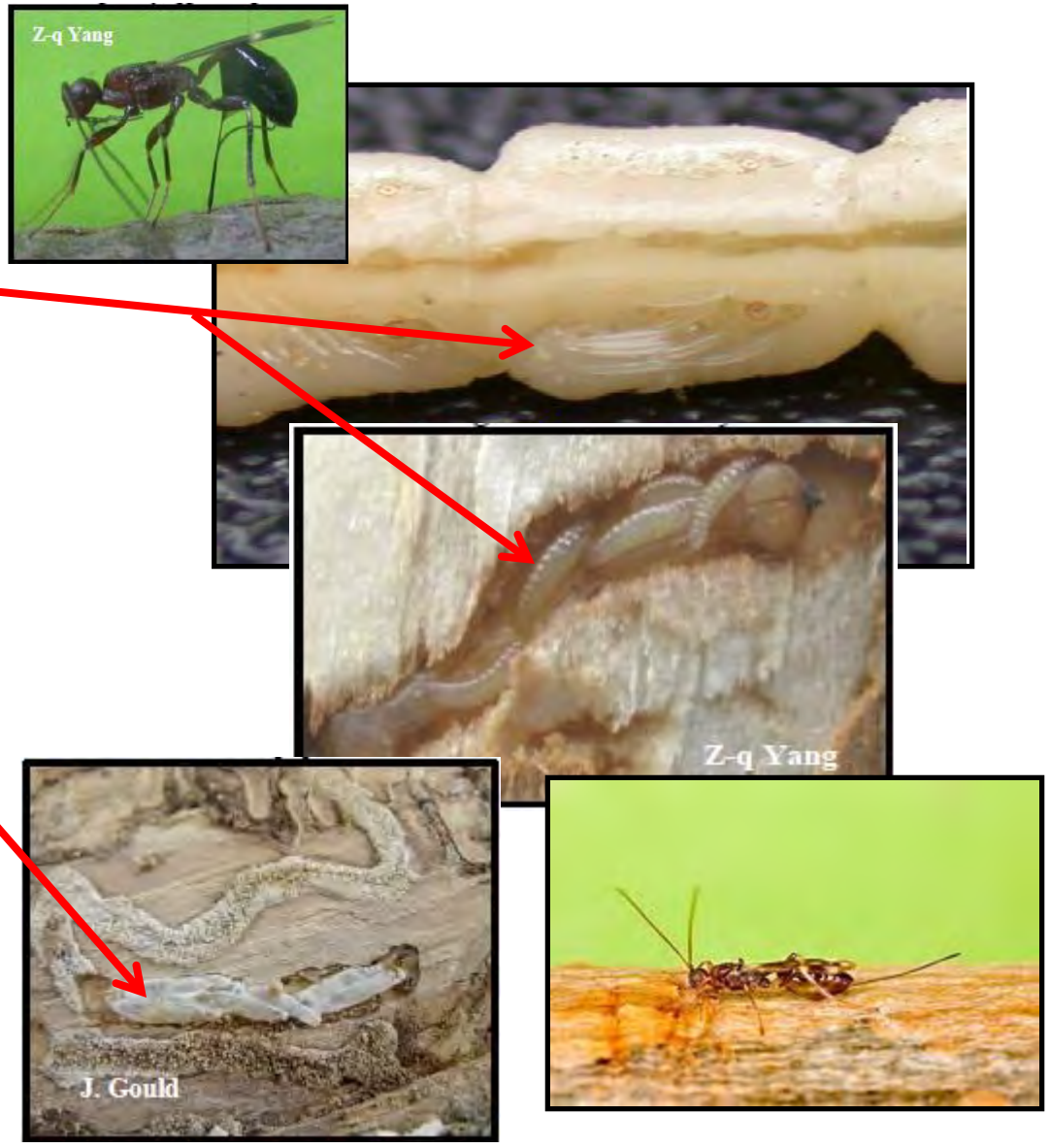
- Females of this species lay a single egg inside an EAB egg
- This occurs on the bark of trees
- The wasp larva consumes the egg contents, transforms into an adult and chews its way out through a tiny hole
- A single adult female *O. agrili* can kill up to 62 EAB eggs
- *O. agrili* has at least two generations per year



An EAB egg that has been parasitized by *O. arili*.

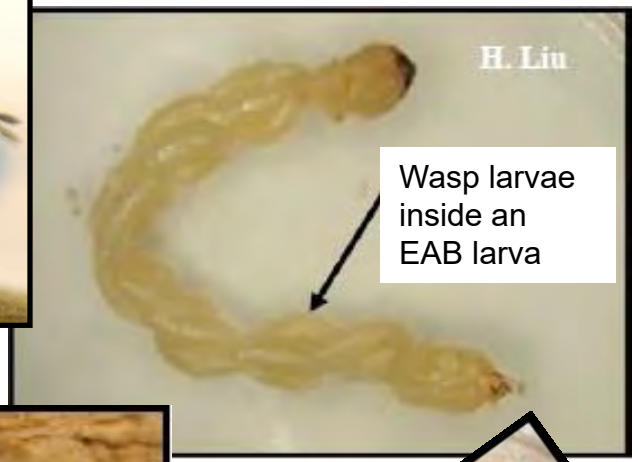
EAB Parasitoids: *Spathius agrili*

- Females of this species drill through the tree's bark to lay eggs on the outside of an EAB larva
- Each wasp can lay up to 20 eggs
- The wasp larvae feed on the EAB larva and spin cocoons in the EAB gallery before emerging as adults
- This cycle occurs 3-4 times throughout the summer and fall



EAB Parasitoids: *Tetrastichus planipennisi*

- Females of this species drill through the tree's bark to lay eggs on the inside of an EAB larva
- A single EAB larva can have up to 130 *T. planipennisi* larvae in it
- The wasp larvae feed inside the EAB larva most of their lives. They leave the EAB larva to pupate under the bark, where they emerge as adults.
- This wasp has at least 4 generations per year



Effectiveness of Bio-control

Biological Control is a Long-term Management Tool

- Bio-control is not likely to significantly impact the first wave of EAB that moves through an area because:
  - EAB populations are too high for parasitoids to kill them all
  - It takes time for parasitoid populations to build up
- After the EAB populations in an area decline, parasitoids may keep them low so that ash trees can survive.
- Having established parasitoid populations in an area may reduce or eliminate the need to treat protected ash with pesticides.

Best Management Practices

You've heard about invasive species and their detrimental effects on both individual trees and ecosystems at large. But did you know that several of Indiana's most problematic invasive species are here directly because of green industry activities?

Green industry professionals are uniquely positioned to incorporate invasive species management practices into their everyday work. In an increasingly environmentally-conscious social climate, marketing your adoption of best management practices for invasive species mitigation in work areas and in the broader landscape can be a major selling point.

Minimize EAB Spread

EAB is spread to new areas in infested wood material. To minimize spread after ash tree removals:

- Mulch all branches larger than 1” diameter
- Do NOT transport whole ash logs long distances
- If leaving firewood for clients, remind them to burn it on site
- Dispose of wood waste locally

Chipping infested wood smaller than 1” square kills EAB larvae

Emerald Ash Borer | Newly reported host

for Green Industry Professionals

White Fringetree

EAB was recently (10/14) discovered on a native species of fringetree *Chionanthus virginica*..

- Not a new host.
- Damage not noticed before because stem dieback was common before EAB occured

Emerald Ash Borer | EAB and Your Business

for Master Gardeners

REMEMBER: Plant Diversity!

Part of the reason EAB is a huge problem in the built environment is that ash trees were overplanted!

Remember the **10-20-30 rule** when making new installations. Never plant more than: 10% of one tree species, 20% of one genus, 30% of one family. Following this rule enhances the resiliency of the urban forest to the next invasive pest.

New Installations

When replacing ash trees, avoid planting known invasive species, and use native plants when possible.

Norway maple, Japanese barberry, and burning bush are commonly-used landscape plants with proven invasive characteristics. Familiarize yourself with invasive plant species and don't use them in installations:

IN Invasive Plant List

Native plants tend to be better behaved, so using them whenever possible is a sound choice. Check out a list of landscape-worthy natives here:

Landscaping Natives

Emerald Ash Borer | Situation and Management

for Master Gardeners

We want to hear your thoughts

Was this training program helpful? Do you have suggestions for improvements or feedback for the Purdue EAB Outreach Team?

Please send a message to csadof@purdue.edu

Thank You!

You will now be directed to the final quiz and certificate of completion.

We appreciate the time you've spent learning about emerald ash borer and its management. We hope you will be more prepared to deal with this devastating pest in your area.

Additional information is available at:

EAB in Indiana

Get the most up to date information on EAB and other forest pests from the experts. Check out EAB University webinars!

EAB University